To: Argyropoulos, Paul[Argyropoulos.Paul@epa.gov]; Lie, Sharyn[Lie.Sharyn@epa.gov]; Korotney, David[korotney.david@epa.gov]
Cc: David DeRamus[david.deramus@bateswhite.com]; marc.chupka@brattle.com[marc.chupka@brattle.com]; Lindsay Fitzgerald[lfitzgerald@biodiesel.org]; Anne Steckel[asteckel@biodiesel.org]; aweber@marciv.com[aweber@marciv.com]
From: Larry Schafer
Sent: Thur 2/27/2014 10:41:31 PM
Subject: Biodiesel Carbon Analysis Support Files
DESCRIPTION of Carbon Analysis Support Files Jan 2014.docx
ATT00001.txt
Jacobsen Feedstock Prices 2011 to 2013.xlsx
Overview of WAEES Model.pdf
Reassessment of life cycle greenhouse gas emissions for soybean biodiesel (4).pdf
dgd-sum-120112.pdf
d1-15biodieselprofitability.xlsx
2010-3851.pdf ← federal register notice (public document)
Biodiesel GHG Summary.xlsx
2014.01.15 FINAL VERSION OF CALCULATIONS.xlsx
15day-cornoil-bd-sum-022112.pdf
EIA Biodiesel Production Report Oct 2013 Data copy.pdf

Paul, Sharyn, David:

It was great meeting you and the rest of the EPA team last week. As discussed, attached are the support files for our analysis; apologies for the large size, but some of the PDFs are a bit big, and I thought you would find it helpful to have them all in one place. The shortcut/summary of our calculations is "2014.01.15 Final version of calculations.xls". Feel free to call if you have any questions or want to discuss further.

If you have questions or comments, then please let me know.

Thanks

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Carbon Analysis Support Files

Greenhouse Gas Emissions. These files provide the background support data that were utilized to calculate GHG reductions from various feedstock pathways (relative to petroleum diesel). The EPA final rule was the basis for most calculations. "Best available data" calculations included more recent work by USDA/University of Idaho, the CARB distillers corn oil pathway, and the CARB renewable diesel pathway. Files include the following:

- 2010-3851.pdf
- Reassessment of life cycle greenhouse gas emissions for soybean.pdf
- 15day-cornoil-bd-sum-022112.pdf
- dgd-sum-120112.pdf
- Biodiesel GHG Summary.xls.

Feedstock Utilization and Pricing. These files document the feedstocks utilized to produce biodiesel in the United States. The information from U.S. DOE-EIA is for the domestic biodiesel industry. There is no public information for feedstock utilization by renewable diesel producers. However, industry stakeholders provided input that only three (3) types of feedstock are currently utilized; animal fats, yellow grease, and distillers corn oil. Feedstock pricing information is from The Jacobsen, a fee based subscription service. Files include the following:

- EIA Biodiesel Production Report Oct 2013 Data copy.pdf
- Jacobsen Feedstock Prices 2011 to 2013

Biodiesel Production Costs. These files include the 3rd party production cost model from Iowa State University and a summary of both the GHG and cost calculations prepared by Bates White. In addition, an overview of the WAEES model utilized to forecast two scenarios in 2014 is available. Files include the following:

- D1-15biodieselprofitability.xlsx
- 2014.01.15 FINAL VERSION OF CALCULATIONS.xlsx
- Overview of WAEES Model. Pdf

	Soybean Oil (Illinois) crude/degummed	Canola Oil - RBD (Chicago)	Bleachable Fancy Tallow - Renderer (Chicago)	Choice White Grease (Chicago)	Yellow Grease (Illinois)	Stabiliazed Poultry Fat (Delmarva delivered)	Distiller's Corn Oil (IL)
2011 Jan	53.771	60.746	47.150	43.625	39.575	37.438	
Feb	54.137	61.032	47.513	45.974	41.395	43.645	
Mar	53.965	61.055	49.522	49.478	45.674	47.152	
Apr	56.639	63.171	51.588	50.850	46.300	48.375	
May	56.080	62.239	52.476	51.429	46.482	48.524	
Jun	55.729	61.626	54.048	52.546	47.028	45.227	
Jul	55.262	62.262	53.800	52.663	46.669	44.600	
Aug	54.350	61.595	49.565	49.348	44.707	45.304	
Sep	54.962	61.066	50.071	48.500	43.827	44.893	
Oct	51.992	59.011	47.600	46.351	43.202	44.393	
Nov	51.778	59.337	44.405	40.798	36.857	39.512	
Dec	50.292	58.209	47.119	41.202	36.015	37.708	
2012 Jan	51.108	58.133	44.200	40.300	35.125	38.200	37.313
Feb	52.406	59.281	45.750	45.265	38.850	40.863	43.375
Mar	53.420	61.056	48.045	49.000	42.182	45.750	44.818
Apr	54.942	62.948	47.300	47.389	41.038	45.188	42.175
May	50.771	60.385	48.932	49.131	41.625	44.784	42.477
Jun	49.552	60.367	45.548	44.803	37.869	41.952	37.762
Jul	54.419	64.308	45.452	43.756	36.810	40.012	36.476
Aug	52.329	63.731	44.630	44.810	37.174	40.283	37.174
Sep	53.433	64.228	45.526	45.197	38.132	41.026	39.763
Oct	50.187	62.070	39.717	38.000	34.690	37.913	36.065
Nov	48.317	59.417	34.000	33.903	30.500	35.100	29.988
Dec	49.617	58.736	36.300	36.727	33.238	36.450	34.500
2013 Jan	51.557	60.016	40.095	40.191	36.476	38.595	36.000
Feb	52.244	60.953	40.097	41.462	37.132	41.000	36.750
Mar	51.250	60.400	42.550	42.971	37.538	41.000	36.838
Apr	51.626	64.557	43.250	43.132	37.898	38.966	36.716
May	52.541	64.291	41.796	40.895	37.080	37.500	36.057
Jun	51.330	61.517	45.000	45.036	38.100	36.500	35.400
Jul	48.377	57.400	45.409	46.205	37.807	36.421	37.023
Aug	45.890	52.413	42.909	41.702	35.028	36.091	37.546
Sep	45.638	51.182	40.645	39.981	34.635	36.438	36.738
Oct	44.161	48.380	33.652	32.825	28.533	29.489	29.261
Nov	40.982	47.502	35.132	32.632	26.197	24.868	27.592
Dec	39.731	45.552	35.611	33.329	27.658	27.553	29.566

NOTE: The Jacobsen is a subscription based service. Information in this file cannot be utilized for other purp

ED-000313-0365_00002630

must be cited.

Overview of WAEES Model

Prepared for:

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MARC IV

and

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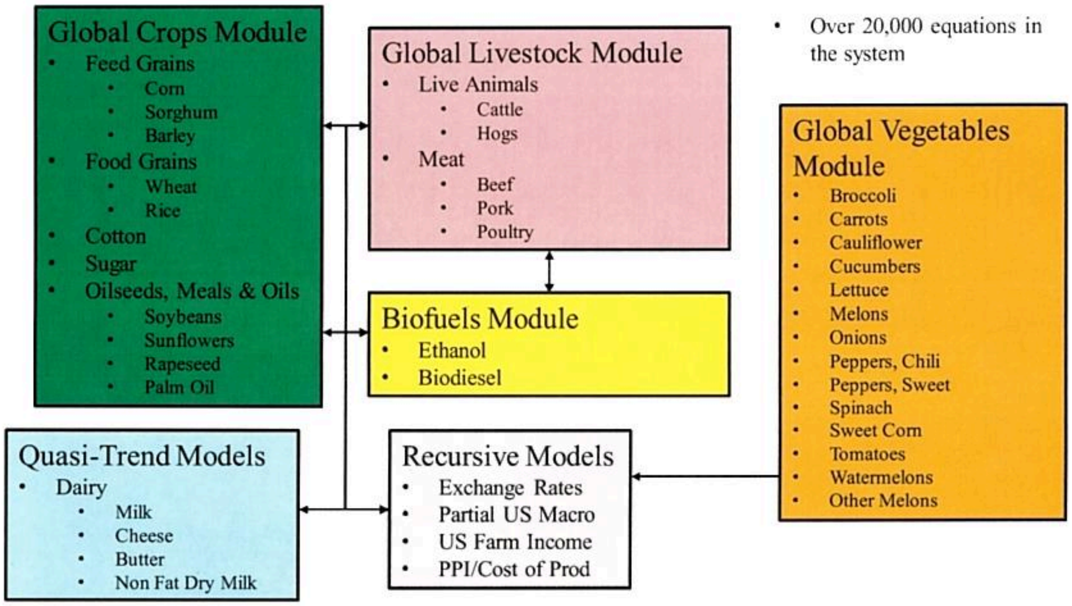
1/19/2014

Overview of the WAEES Modeling System

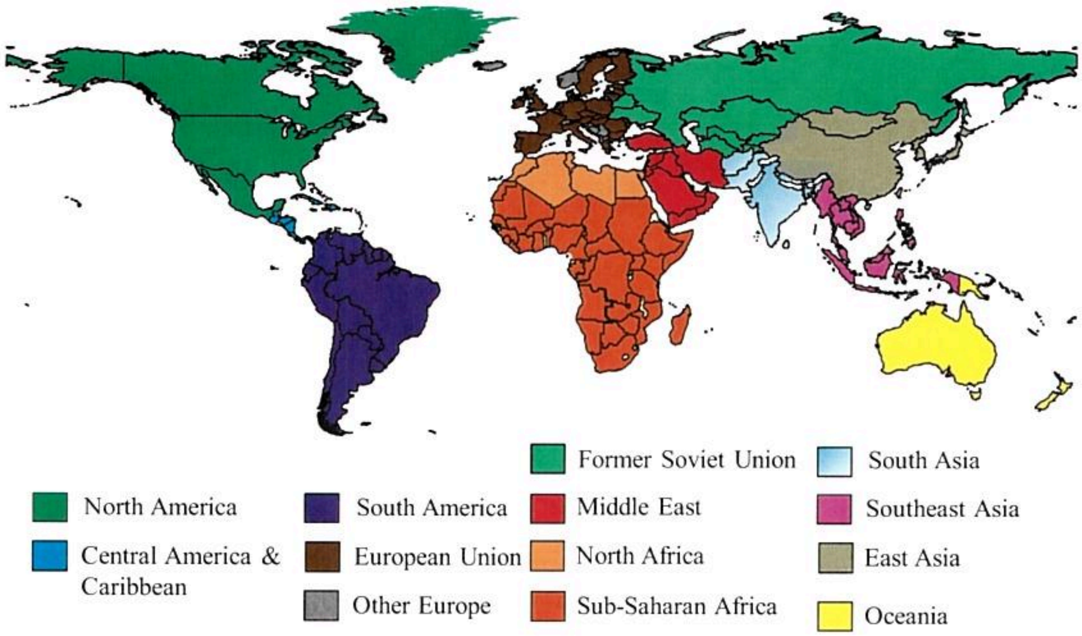
The WAEES partial equilibrium modeling system is made up of a set of global econometric models emulating the behavior of the global agricultural sector. The partial equilibrium models can be broken down into crops, livestock and biofuels components encompassing feed grains, food grains, cotton, sugar, oilseeds, ethanol, biodiesel, beef, pork, and poultry.

WAEES Partial Equilibrium Models



The WAEES models cover 42 countries/regions with an additional 12 regional aggregates including the world total. WAEES follows USDA's reported data coverage which may mean that a zero is reported for a particular commodity which USDA does not cover or has discontinued covering. USDA currently covers at least 90 percent of global production; therefore, the countries which are omitted represent a small portion of total global production. Specifically the WAEES model includes Canada, Mexico, the United States, Caribbean and Central America, Argentina, Brazil, Bolivia, Chile, Paraguay, Uruguay, Other South America, the European Union 28, Other Europe, Russia, Ukraine, Uzbekistan, Other Former Soviet Union, Saudi Arabia, Turkey, Other Middle East, China, Japan, South Korea, Taiwan, Other East Asia, India, Pakistan, Other South Asia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, Vietnam, Other Southeast Asia, Australia, Other Oceania, Egypt, Other North Africa, Kenya, South Africa, and Other Sub-Saharan Africa. WAEES also reports projections on crop area, yield and production for each of the EU-28 countries.

WAEES Regions follow the USDA Regions

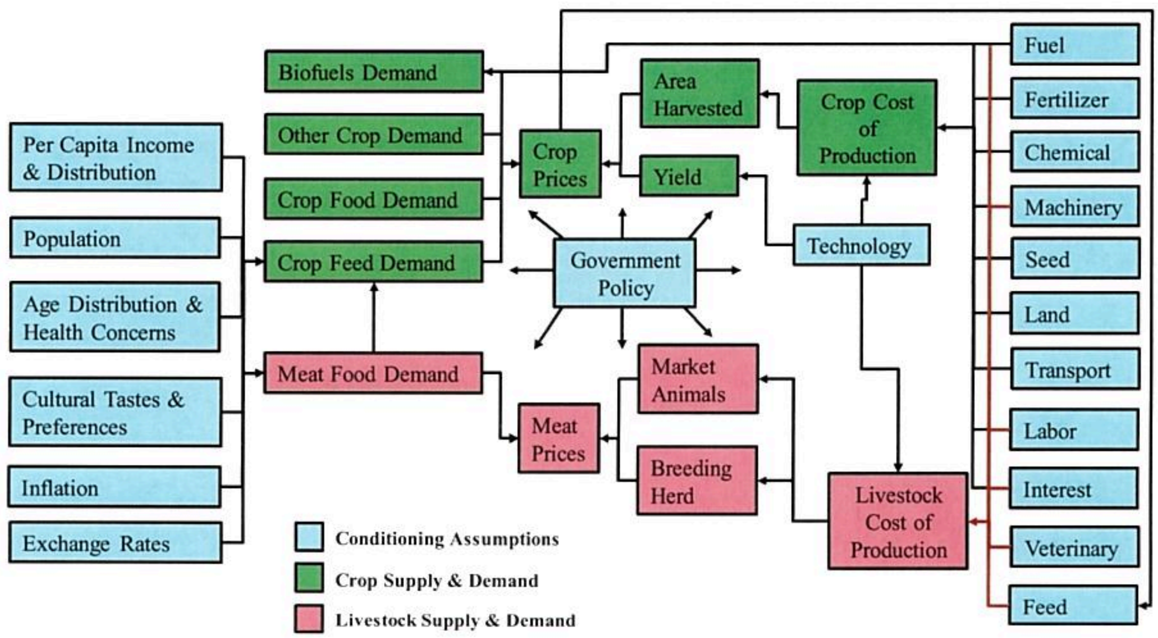


Partial Equilibrium Models

Each partial equilibrium module is broken down into commodities with a system of structural equations capturing the supply and demand components for each of them. The drivers of these equations are theoretically derived based upon the behavioral postulates from economic theory of profit maximization by the market participants and utility maximization by consumers subject to various domestic and international trade policies. The diagram below illustrates the inter-linkages of the crops and livestock model. In the diagram, the blue boxes represent the key drivers (conditioning assumptions) of the agricultural sector including income, population, culture, inflation, exchange rates, domestic and trade policy, technology and input costs. The green boxes are an aggregate approximation of the crops sector. As relevant, each box represents an equation for each commodity covered. For example, there are specific feed demand equations for corn, sorghum, barley, soybean meal, sunflower meal, etc. The pink boxes are an aggregate approximation (within the diagram) of the detailed livestock sector model encompassing beef, pork and broilers. The diagram illustrates how income, population, and other factors drive food demand for crops and meats. Crude oil prices (and policies) drive the demand for biofuels. As demand increases, crop prices increase providing an incentive for production expansion. Technology growth drives yield expansion providing much of the needed production. Crop area may also grow to meet demand needs although in developed countries this often amounts to tradeoffs among crops. Ultimately supply and demand are balanced via commodity prices. If demand is stronger than supply, commodity prices increase until demand growth is slowed and supply growth is increases enough for supply and demand to balance.

Partial Equilibrium Modeling System

(Conceptual Framework Representation for One Country)



The WAEES partial equilibrium models solve iteratively to find equilibrium by balancing global supply and demand. This occurs at the individual country level for each commodity. Most countries are at least somewhat open to trade albeit with tariffs. The trade diagram below illustrates conceptually how global supply and demands are balanced within a "global" price equilibrium solution. Typically a large exporting country is chosen as the residual supplier for the world. The choice of this country does not affect the solution. The commodity price in the residual supplying country is solved for by assuming an initial level of exports. This price is then transferred to other countries through trade barriers, transportation costs, and exchange rates. Based on a given price level, each country determines how much it is willing to supply or demand at that price and subsequent how it wants to import or export. Occasionally a country has tariffs high enough that no trade will occur or only a fixed amount of trade will occur at the lower tariff level. Note that in those countries internal prices may not reflect the world level of prices because supply and demand must be balanced from domestic sources. After the supply and demand in each country is determined and the implied trade position, these trade positions are summed to find the new level of exports for the residual supplying country replacing the initial assumption. The process then repeats itself until prices adjust to balance global supply and demand. For example, if the sum of trade across all other countries is lower than the initial starting assumption for the residual supplying country, the price level in the residual supplying country will fall to balance supply and demand. This lower price level will then get transferred to all other countries affecting their supply and demand and ultimately net trade positions and of course replace the exports again in the residual supplying country. This process continues until global supply and demand balance.

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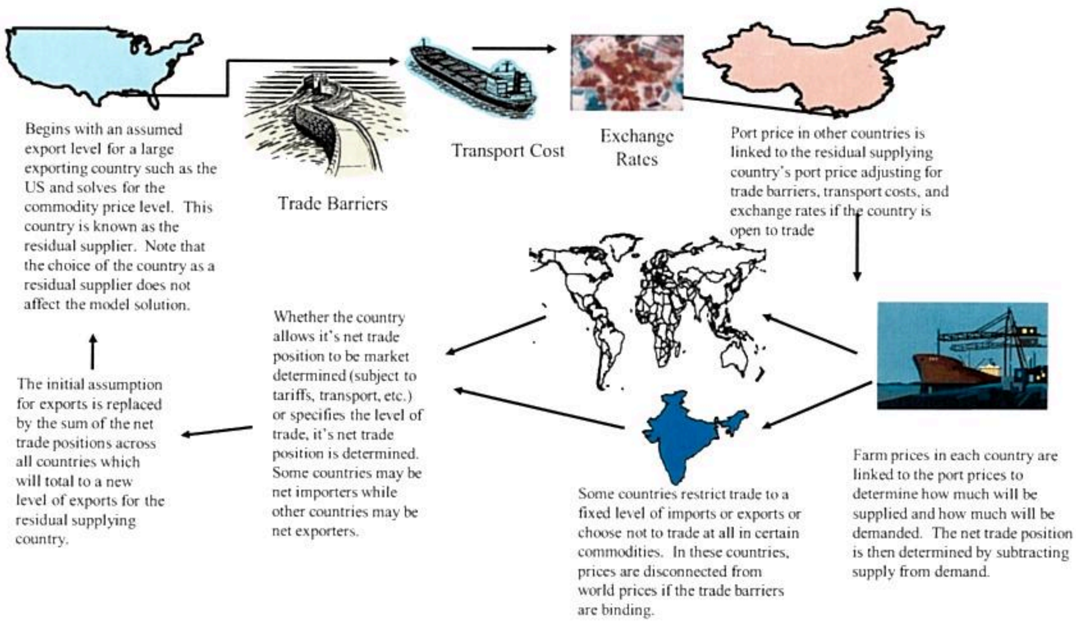
How do partial equilibrium models solve for a global supply and equilibrium price?



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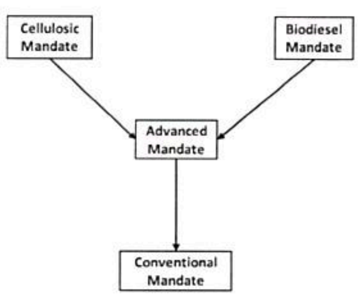
An Example of the US Partial Equilibrium Model for the Biofuels Sector

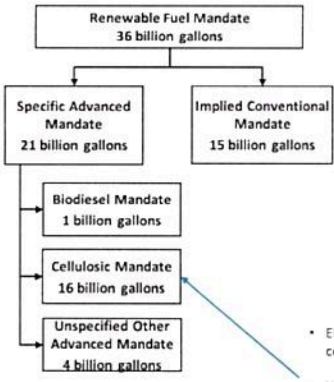
Within the WAEES model, the US ethanol and biodiesel sectors are set up as partial equilibrium models with supply and demand equations and an endogenous ethanol and biodiesel price. The structure of the model has its roots in the ethanol specifications documented by John Kruse, Patrick Westhoff, Seth Meyer, and Wyatt Thompson in a 2007 journal article in AgBioForum entitled, "Economic impacts of not extending biofuel subsidies." With the second Renewable Fuel Standard, these original specifications have been updated to reflect the hierarchical system of mandates. The biofuels mandates require compliance with each specific mandate type including biodiesel, cellulosic, advanced and the overall renewable fuel mandate. The rational for different mandates in the legislation was to encourage biofuel producers to move towards feed stocks that provided the greatest level of greenhouse gas (GHG) reductions compared with conventional petroleum. The term "advanced biofuels" was used to describe biofuels that reduced GHG emissions by at least 50 percent compared with a 20 percent reduction requirement for conventional feed stocks. Cellulosic derived biofuels must reduce GHG emissions by 60 percent. Compliance with the mandates by the obligated parties is enforced by the EPA through as system of Renewal Identification Numbers (RINS) assigned to each type of biofuel produced. Obligated parties must demonstrated that they have met their assigned obligations through the number of RINS they have for each type of fuel. Theoretically there could be a specific RIN value for each type of mandate – cellulosic, biodiesel, advanced, and conventional, if each mandate was binding. Mandates are binding when the market is forced by policy to produce more than what normal economic conditions would suggest. The advanced biofuels are typically more expensive to produce than conventional biofuels resulting in those mandates being more binding than conventional biofuels mandates. Therefore RIN values (or prices) are typically significantly higher for advanced biofuels than conventional biofuels.

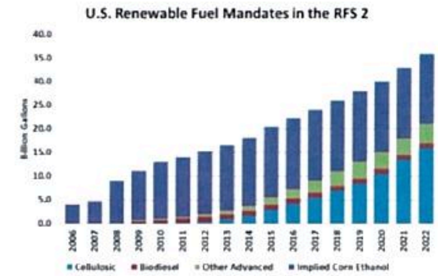
Hierarchical RINS Modeling



- Theoretically there can be 4 different RIN prices specific to each mandate if all the mandates are binding.
- Mandates are binding when the market is forced by policy to produce more than what normal economic conditions would suggest.
- Given the hierarchy of the mandates, it must be the case that RIN values for biodiesel are greater than or equal to advanced RIN values and advanced RIN values must be greater than or equal to conventional RINS. This is because biodiesel RINS can be used as advanced RINS and advanced RINS can be used as conventional RINS. (This process is referred to as demotion.)
- Biodiesel RINS can have the same value as advanced RINS if the biodiesel mandate is less binding than the advanced mandate.

US Biofuels Mandates in 2022

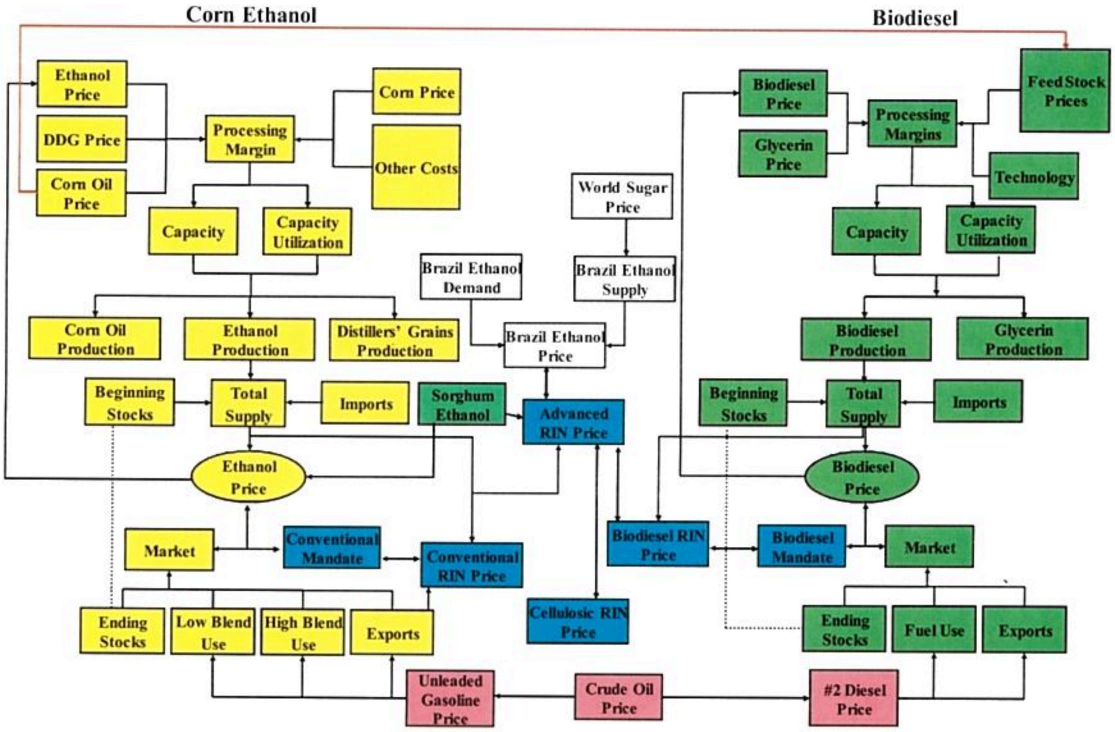




- EPA has waived the cellulosic mandate in 2011 and 2012 because cellulosic biofuels are still very expensive to produce.
- While the cellulosic mandates has been waived, the overall advanced mandate continues to be retained forcing more demand for other advanced fuel feed stocks such as biodiesel and sugarcane ethanol.

A detailed diagram of the US biofuels models is presented below. The demand for biofuels is largely mandate driven. However, if crude oil price edge higher it is possible for ethanol demand to be driven by market forces although the blend wall presents another hurtle. The supply of biofuels is driven by the profit margins of the biofuel plants. Profit margins are derived by subtracting the cost of the feed stocks and other variable costs of production from the valued of the products. In the case of ethanol, the value of the ethanol plus the value of the byproducts including corn oil and distiller's grains form the gross returns. The cost of ethanol is composed of the feed stock cost, primarily corn, and the other inputs. In the case of biodiesel, the value of biodiesel and the byproduct glycerin form the gross returns. The cost of producing biodiesel is composed of the feed stock costs such as vegetable oils, waste oils, corn oil and other inputs. The respective margins for ethanol and biodiesel drive capacity expansion in the longer term and capacity utilization in the short term for each sector. Equilibrium between biodiesel supply and demand is found by solving for the biodiesel price.

US Biofuels Partial Equilibrium Models



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The WAEES Global Modeling Process

Forecast Assumptions

WAEES begins each semi-annual forecast by developing a set of conditioning assumptions that will be used for the forecast. These assumptions include the critical domestic and trade policies affecting agriculture and biofuels in each country; macroeconomic conditions such as per capita income growth, population growth, inflation rates, and exchange rates; technology assumptions such as crop yield growth; and key cost of production drivers such as interest rates, petroleum prices, wage rates, and other trends in tastes and preferences. Infrastructure constraints and land area expansion assumptions are also outlined in this process. These assumptions are direct inputs into the WAEES global agricultural partial equilibrium models.

Historical Data

The second step in the process is updating all historical data to the latest numbers. A large portion of the historical supply and demand data is drawn from USDA's Production, Supply, and Disposition (PSD) database. Historical data on crop area, yield, and production for each of the EU-28 countries is taken from Eurostat and supplemented with data from each of the country Ministries of Agriculture as needed. Some historical data such as sugarcane and sugar beet area harvested is taken from FAOSTAT, but the data is reviewed for consistency prior to being used in the models. Historical data on commodity prices are taken from a variety of sources including the respective Ministries of Agriculture (or equivalent) in each country, USDA, FAO, etc. Historical government policy information is gathered from USDA Gain Reports, the WTO, OECD, FAO, and the respective Ministries of Agriculture (or equivalent) in each country.

The timing of historical data releases determines when the WAEES forecasts are completed. The critical updates for PSD's global livestock data occur in April and October. The global crops data is updated more frequently throughout the year. Since the size of the southern hemisphere crops are generally available in April/May and the size of plantings in the northern hemisphere crops are generally known, WAEES conducts the first of the semiannual forecasts over the month of May targeting the beginning of June for release of the forecast numbers. The second forecast is typically done over the month of November targeting the beginning of December for a release of the forecast numbers. At this time of the year, the northern hemisphere crop sizes and the southern hemisphere plantings are generally known.

Model Development and Equation Updates

The WAEES global partial equilibrium models are in a constant state of review to ensure that the equation are performing adequately, the model structure is adapted to changes in the marketplace, changes in data sources are captured, and new coverage is added as necessary. While WAEES does not keep an exact count on the number of equations in the system, it now exceeds 20,000 equations. The performance of the behavioral equations within the system are continuously monitored within the system based on their percent root mean square errors, consistency with market behavior, and their recent pattern of historical errors. Prior to each forecast, the equations are reviewed and replaced as needed.

Model Calibration and Adjustment

After the historical data has been updated, each equation is recalibrated to the updated historical data. After reviewing the equation performance as per the description above, the model adjustment factors are set for the first forecast year. These adjustments are set based on a weighted average of the equations errors over the previous 3-5 years in the model. In 99.5% of the equations this adjustment factor is held constant over the forecast horizon of 2013 through 2030. There are a few equations, particularly in the livestock sector, where adjustments are used to generate the livestock cycles.

Generating the forecast

After capturing the forecast assumptions, updating the historical data, reviewing the model equations, and calibrating the model, the model is then solved to generate a global forecast of commodity prices that balances supply and demand within each country and around the world. Since the commodities are highly interrelated within the model sometimes the forecast assumptions generate unexpected results and/or push the model into a region outside the experience based on historical data. The global solution is carefully reviewed and the equation results are evaluated based on direction and magnitude of response, and if necessary, the model equations are adjusted and the model is re-solved for a new global solution. These corrections are usually small or not needed, but some scenarios can push the model into untested ranges.

REASSESSMENT OF LIFE CYCLE GREENHOUSE GAS EMISSIONS FOR SOYBEAN BIODIESEL

A. Pradhan, D. S. Shrestha, J. Van Gerpen, A. McAloon, W. Yee, M. Haas, J. A. Duffield

ABSTRACT. *This study updates the life cycle greenhouse gas (GHG) emissions for soybean biodiesel with revised system boundaries and the inclusion of indirect land use change using the most current set of agricultural data. The updated results showed that life cycle GHG emission from biodiesel use was reduced by 81.2% compared to 2005 baseline diesel. When the impacts of lime application and soil N_2O emissions were excluded for more direct comparison with prior results published by the National Renewable Energy Laboratory (NREL), the reduction was 85.4%. This is a significant improvement over the 78.5% GHG reduction reported in the NREL study. Agricultural lime accounted for 50.6% of GHG from all agricultural inputs. Soil N_2O accounted for 18.0% of total agricultural emissions. The improvement in overall GHG reduction was primarily due to lower agricultural energy usage and improved soybean crushing facilities. This study found that soybean meal and oil price data from the past ten years had a significant positive correlation ($R^2 = 0.73$); hence, it is argued that soybean meal and oil are both responsible for indirect land use change from increased soybean demand. It is concluded that when there is a strong price correlation among co-products, system boundary expansion without a proper co-product allocation for indirect land use change produces erroneous results. When the emissions associated with predicted indirect land use change were allocated and incorporated using U.S. EPA model data, the GHG reduction for biodiesel was 76.4% lower than 2005 baseline diesel.*

Keywords. *Biodiesel, Biofuel, Greenhouse gas emissions, Land use change, Life cycle analysis, Soybean.*

Biofuels are becoming popular alternatives to fossil fuels, with state and federal policies, such as the Renewable Fuel Standard (RFS2), significantly increasing their demand over the past several years (EPA, 2010a). Although biofuels have the potential to become completely renewable, their production with today's technology requires some nonrenewable resources, e.g., synthetic fertilizers are used to improve yields, and fossil fuels are used for powering farm equipment.

The first comprehensive life cycle inventory (LCI) for biodiesel (BD) produced in the U.S. from soybean oil was published by the National Renewable Energy Laboratory (NREL) (Sheehan et al., 1998). The purpose of the NREL study was to conduct a life cycle assessment (LCA) to quantify the energy and emissions associated with the production and use of soybean biodiesel and compare it to petroleum diesel. The study took into account the emissions associated with soybean agriculture, transport, crushing, oil transesterification, biodiesel transport, and use of biodiesel in a city bus. The study used 1990 soybean production data from the Farm Costs and Return Survey (FCRS) conducted by the USDA. The data for soybean crushing came from a performance study conducted in 1981. The study used a 1994 transesterification model from a single commercial transesterification facility.

The NREL study reported that soybean biodiesel reduced carbon dioxide (CO_2) emissions by 78.5% compared to petroleum diesel. The reason behind this reduction is that biomass-derived fuels participate in the relatively rapid cycling of carbon to and from the atmosphere. Biomass-derived carbon that ended up as CO_2 leaving the tailpipe of a city bus was subtracted from the total CO_2 as part of the biological recycling of carbon.

The objective of this study is to update the life cycle greenhouse gas (GHG) emissions calculations based on the most recent complete set of data for soybean biodiesel production via base catalyzed transesterification. Even though more current partial data for agriculture were available, the data used in this article are from 2006. It is important to use agricultural data from a single year, as agricultural data vary significantly from year to year depending on factors such as weather and pest infestation. The year 2006 was the most recent year that had a complete set of agriculture data available. This study compares the new LCA result with the NREL result and provides an explanation of the reasons for any differences. This study also points out the potential pitfalls of the system boundary expansion approach for impact assessment of indirect land use change, including the

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assumption that this approach will automatically account for co-product allocation.

METHODOLOGY

This study takes two different approaches; the first is the "base case," the methodology of which is consistent with the NREL's attributional LCA. Attributional LCA (ALCA) is a "business as usual" method that accounts for environmentally relevant physical flows to and from a product system. ALCA uses average values based on normal, current business practices. ALCA does not include any indirect effects that are not directly related to the production of biodiesel. The second approach is the "consequential" LCA, which includes factors such as indirect land use change. Consequential LCA (CLCA) aims to predict the consequences if changes are made to an established process. CLCA includes indirect changes in addition to direct effects.

The system boundary for the base case in this study is similar to that of the NREL study, except for inclusion of the use of agricultural lime (to improve soil pH) and soil nitrous oxide emission, and exclusion of oil transport. The list of inputs and outputs for the attributional LCA is shown in table 1. Agricultural lime was included in the base case because it is used periodically on soybeans and was inadvertently omitted from the NREL analysis. The impact of soybean oil transport was studied separately and not included in the base case because, for the most part, the soybean oil biodiesel plants considered in this study are co-located with soybean crushing plants. The GHG emissions were estimated from energy and material inputs in the production process. The emissions were calculated by multiplying the inputs by the corresponding emission factor. The data for estimating the effect of indirect land use change were borrowed from a recent EPA analysis (EPA, 2010b).

Three major anthropogenic greenhouse gases (CO_2, CH_4, and N_2O) were used to estimate the net GHG emissions. All emissions were reported as CO_2-equivalent (CO_2e) emissions. The CO_2e value indicates a GHG's global warming potential (GWP), as advocated by the Intergovernmental Panel on Climate Change (IPCC). GWP indicates the relative strength of radiative forcing (RF) of a GHG compared to CO_2 integrated over time. Therefore, CO_2 has a GWP of unity. The IPCC Second Annual Report

Table 1. Energy requirements of the inputs without co-product allocation.

Inputs	Quantity Used	Embedded Energy	gCO_2e Factor	gCO_2e [e]
Soybean agriculture	(per ha)			
Diesel	33.3 L [a]	35.9 MJ L^{-1} [b]	89.7 MJ^{-1} [c]	107,233.7
Gasoline	12.8 L [a]	32.4 MJ L^{-1} [b]	90.9 MJ^{-1} [c]	37,698.0
LP Gas	2.0 L [a]	23.7 MJ L^{-1} [b]	76.1 MJ^{-1} [d]	3,607.1
Natural gas	4.1 m^3 [a]	36.6 MJ m^{-3} [b]	72.4 MJ^{-1} [d]	10,864.3
Nitrogen	3.3 kg [a]	-	3.6 g^{-1} [d]	11,880.0
Phosphorus	12.1 kg [a]	-	1.2 g^{-1} [d]	14,520.0
Potassium	22.4 kg [a]	-	0.8 g^{-1} [d]	17,920.0
Lime	463.7 kg [a]	-	0.6 g^{-1} [b]	278,220.0
Seed	68.9 kg [a]	-	189.3 kg^{-1} [k]	13,042.8
Herbicide	1.6 kg [f]	-	25.8 g^{-1} [d]	41,280.0
Insecticide	0.04 kg [f]	-	30.0 g^{-1} [d]	1,200.0
Electricity	17.1 kWh [a]	3.6 MJ kWh^{-1} [g]	208.4 MJ^{-1} [d]	12,829.1
			Subtotal:	550,295.0
Soil N_2O emission	(per ha)			120,468.5
Soybean transport	(per ha)			56,464.3
Soybean crushing	(per L of BD)			
Electricity	212.3 Wh [h]	3.6 MJ kWh^{-1} [g]	208.4 MJ^{-1} [d]	159.3
Natural gas	0.11 m^3 [h]	36.6 MJ m^{-3} [b]	72.4 MJ^{-1} [d]	291.5
Hexane	11.1 g [h]	-	0.2 g^{-1} [b]	2.2
			Subtotal:	453.0
Biodiesel conversion	(per L of BD)			
Electricity	44.6 Wh [h]	3.6 MJ kWh^{-1} [g]	208.4 MJ^{-1} [d]	33.4
Steam at 10.3 bar (150 psi)	124.1 g [h]	2.0 MJ kg^{-1} [i]	119.1 MJ^{-1} [j]	29.6
Methanol	96.7 g [h]	20.1 MJ kg^{-1} [d]	67.7 MJ^{-1} [d]	131.6
Sodium methylate	2.7 g [h]	-	7.9 g^{-1} [k]	21.3
Hydrochloric acid	0.5 g [h]	-	13.5 g^{-1} [k]	6.8
			Subtotal:	222.7
Biodiesel transport and distribution	(per L of BD)			22.5
Biodiesel combustion	(per L of BD)			21.7

[a] 2006 ARMS and ERS data (data were obtained from the USDA through special request).
[b] ANL, 2010.
[c] DOE, 2008.
[d] EPA, 2010d.
[e] Product of columns 2, 3 (when applicable), 4, and proper unit conversion factor to get emission in gCO_2e.
[f] NASS, 2007.
[g] Direct unit conversion.
[h] ARS model.
[i] Steam table data.
[j] Natural gas as fuel with 60.8% boiler efficiency (steam generation at 150 psig = 1411 Btu lb^{-1}, and the enthalpy of evaporation from the steam table = 858 Btu lb^{-1}, which gives the total natural gas to steam usage efficiency of 858/1411 = 60.8%).
[k] Sheehan et al., 1998.

ED_000313_O365_00002632

(SAR) assesses the GWP of CH_4 as 21 and N_2O as 310 for a 100-year horizon (IPCC, 1996). The IPCC Third Assessment Report (TAR) re-evaluates the GWP of CH_4 as 23 and N_2O as 296 for the same time horizon (IPCC, 2001). The United Nations Framework Convention on Climate Change reporting guidelines for national inventories were updated in 2006 but continue to require the use of GWP values from the IPCC SAR (UNFCCC, 2006). This requirement of using SAR GWP values ensures that new estimates of aggregate GHG emissions are consistent with estimates developed prior to the publication of the IPCC TAR and the IPCC Fourth Assessment Report (AR4), which re-evaluates the GWP of CH_4 as 25 and N_2O as 298 (IPCC, 2007). In order to comply with UNFCCC reporting standards, this article uses SAR GWP values. The U.S. EPA also follows UNFCCC guideline and uses GWP values from SAR (EPA, 2010c) in its renewable fuel standard (RFS2) life cycle analysis.

The GHG emissions for soybean biodiesel production were expressed as grams of CO_2-equivalent (gCO_2e). The energy inputs were multiplied by the embedded energy (low heating value for all fossil fuels) of the input and then multiplied by the appropriate GHG factor (table 1). For the non-energy inputs, where energy equivalence is not applicable, the input was directly multiplied by the GHG factor to calculate gCO_2e. The results were compared with 2005 baseline diesel GHG emissions, as required by The Energy Independence and Security Act (EISA) of 2007, to quantify the relative benefits of soybean biodiesel.

Data Description and Assumptions

Soybean Agriculture

At the time of the Sheehan et al. (1998) study, the most recent soybean production data were from the USDA 1990 Farm Costs and Return Survey (FCRS). In this article, all farm input and direct energy data for soybean production are from 2006, the most recent set of soybean survey data available at the time of this study. Agricultural inputs and outputs, such as yields and use of pesticides, vary from year to year. Therefore, mixing and matching agricultural data from different years can produce an unrealistic picture. Temporal variation could be minimized by averaging several years of data, but complete sets of agricultural data are not generally available for multiple consecutive years. Therefore, a complete set of the most recent agriculture data from a single year was used in this study.

In order to ensure that 2006 was not an abnormal year, which could bias the result, we carried out a linear regression analysis on yields from 1980 to 2010. This analysis verified that the yield for 2006 was within the 95% confidence interval (36.4 to 48.8 bu ac^{-1}) of predicted yield. The fertilizer, lime use, and direct energy use (such as diesel, gasoline, and natural gas consumption) were from the 2006 Agricultural Resource Management Survey (ARMS) and National Agricultural Statistics Service (NASS) data compiled by the USDA Economic Research Service (ERS). Chemical data for 2006 were from a chemical survey conducted by NASS (NASS, 2007). The 2006 ARMS and NASS soybean survey provided detailed state-level data for 19 major U.S. states. The state soybean yield data were estimates reported by NASS (NASS, 2010). The national average yield was 2906.7 kg ha^{-1} (43.2 bu ac^{-1}) in 2006. The soybean farm survey data were weighted by state acreage to derive the average quantity used for U.S. soybean production. The CO_2e emission values were from the Excel sheet "emission factors" in EPA data (EPA, 2010d). The CO_2, CH_4, and N_2O emissions for hexane and agricultural lime, not provided in the EPA report, were from the Excel sheet "BD" in the GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model (ANL, 2010). These CO_2e emission values were then converted to CO_2e factors using SAR GWP values.

Soil Emission Data

This study used soil N_2O emissions (not available at the time of the NREL study) from the GREET model (ANL, 2010). N_2O is emitted through (1) direct emissions (including nitrification, denitrification, and volatilization) from the soil to the air, and (2) indirect emissions (including leaching and runoff of nitrate into waters) (Huo et al., 2009). N_2O emissions from the biological fixation of nitrogen are not included in the model, as the IPCC, in the 2006 guidelines, removed biological fixation of nitrogen as a direct source of N_2O (IPCC, 2006).

The GREET model (ANL, 2010) estimates soil N_2O emission using the total amount of nitrogen in the soybean biomass left in soybean fields (aboveground and belowground biomass) and in the nitrogen fertilizer applied. GREET estimates 7.4 g of nitrogen in the biomass per kilogram of soybean produced (200.7 g N bu^{-1} soybean). IPCC suggests an average conversion factor of 1% for the production of N_2O from biomass nitrogen and fertilizer nitrogen (IPCC, 2006). To estimate the total N_2O emission, 1% of the summed nitrogen content from biomass and synthetic fertilizer was multiplied by the factor 1.57 to account for the ratio of the molecular weights of N_2O and N_2, per IPCC recommendations. Using values from the GREET model, the N_2O emission from the soil was estimated to be 388.1 g N_2O ha^{-1} (3.63 g N_2O bu^{-1}).

Soybean Transport

The average hauling distance for soybeans from the point of production to that of processing depends on the crushing capacity of the plant. For an oil crushing plant with an annual capacity of 378 million L (100 million gal), the theoretical minimum hauling distance was calculated to be 56 km (35 mi), assuming a corn-soybean rotation and that the crushing plant was located at the center of a square-shaped agricultural area from which it draws the soybeans (Biodiesel Education, 2012). Because of system inefficiencies, the actual hauling distance would be greater than this. A one-way trip of 81 km (50 mi) was assumed to be the average distance to haul soybeans to the crushing/biodiesel plant using a truck as the mode of transportation (ANL, 2010). This estimation was based on 16 km (10 mi) to transport soybeans from farm to storage and another 64 km (40 mi) to transport soybeans to the crushing/biodiesel plant. The GREET model estimates of CO_2, CH_4, and N_2O emissions for soybean transportation were 512.32, 0.5886, and 0.0133 g bu^{-1}, respectively. Using SAR GWP, the CO_2e for soybean transport was estimated to be 56,464.3 g ha^{-1}

(529 g bu^{-1}) (table 1). The theoretical analysis provided a means of data verification.

Soybean Oil Extraction and Transesterification

This study uses the energy input data for soybean crushing, hexane extraction of the oil, and biodiesel production via alkali-catalyzed transesterification from a biodiesel plant model developed by the USDA-ARS using SuperPro designer (Intelligen, Inc., Scotch Plains, N.J.). The ARS model was prepared from process designs, equipment specifications, costs, and energy consumptions that were provided by technical experts and equipment suppliers to the soybean crushing and biodiesel industry. The model estimates the electrical and thermal energy inputs required for hexane extraction and its subsequent refining and conversion to biodiesel at an annual scale of 38.6 million L (10.2 million gal) of biodiesel, 137,491 Mg of soybean meal, 8,167 Mg of soybean hulls, and 3,975 Mg of crude glycerin. The model used in the analysis allows the plant to generate its own steam from natural gas with a life cycle efficiency of 60.8% (table 1). The model does not represent an industry average, but it provides a blueprint of a specific biodiesel plant based on the best information available from equipment manufacturers and communication with the industry.

Biodiesel Transport, Distribution, and Combustion

The biodiesel transport and distribution data used in this study were taken from the GREET model (ANL, 2010), which estimates a one-way trip of 540 km (335 mi) for biodiesel transport and distribution using a combination of truck, barge, and rail. This estimation was based on 52 km (32 mi) by truck, 68 km (42 mi) by barge, and 373 km (232 mi) by rail to transport the biodiesel to a distribution center, and another 48 km (30 mi) by truck to transport the biodiesel to its final destination. The GREET estimates of CO_2, CH_4, and N_2O emissions for biodiesel transport and distribution were 704.7, 0.81, and 0.0167 g $mmBtu^{-1}$ BD, respectively. Using SAR GWP, the CO_2e for biodiesel transport and distribution was estimated to be 0.7 g MJ^{-1} fuel (22.5 g L^{-1} BD) (table 1).

The CO_2 emission from biodiesel combustion was not included in the model because it is assumed to be equal to the amount of CO_2 captured by soybeans during photosynthesis. Exclusion of CO_2 emission is consistent with the NREL study. The combined N_2O and CH_4 emission from biodiesel combustion was estimated to be 21.7 gCO_2e L^{-1} BD (EPA, 2010d) (table 1).

Co-Product Allocation

In order to provide a consistent comparison to the NREL report, this study used a mass-based allocation method that allocates energy and emissions to the various co-products by their relative weights. The USDA Economic Research Service (ERS, 2009) reported a 2006-2007 U.S. average oil yield of 0.189 kg oil kg^{-1} soybean (11.34 lb bu^{-1}). This extraction rate is higher than the 0.169 kg oil kg^{-1} soybean (10.16 lb bu^{-1}) used in the NREL study. The oil extraction rate for crop year 2006-2007 was used in this study in order to be consistent with the 2006 ARMS agricultural input data. After excluding the hulls and waste material, the soybean produced 20.5% oil and 79.5% meal by weight. Total emissions from biodiesel were allocated between oil and meal accordingly.

Table 2. Base case emissions for biodiesel with co-product allocation.

Subsystem	Allocation Factor (%)	Emissions (gCO_2e GJ^{-1} biodiesel) Before Allocation[a]	After Allocation
Soybean agriculture	18.4	28,128.9	5,175.7
Soil N_2O emission	18.4	6,157.9	1,133.1
Soybean transport	18.4	2,886.2	531.1
Oil recovery	18.4	13,853.2	2,549.0
Biodiesel conversion	89.9	6,810.4	6,122.5
Biodiesel transport	100	688.1	688.1
Biodiesel combustion	100	663.1	663.1
Total		59,187.8	16,862.6
Diesel emissions (gCO_2e GJ^{-1} diesel)[b]			89,668.2
GHG reduction for biodiesel relative to diesel (%)			81.2

[a] From table 1 (last column of table 1 was converted to gCO_2e GJ^{-1} biodiesel using conversion factors of 19,563.3 MJ of energy from biodiesel ha^{-1} and 32.7 MJ L^{-1} of biodiesel).
[b] DOE, 2008.

Transesterification of soybean oil produces biodiesel and crude glycerin. The NREL model of transesterification used a biodiesel to crude glycerin production ratio of 4.7:1 (10,504 kg h^{-1} for biodiesel and 2,235 kg h^{-1} for crude glycerin). According to this ratio, the NREL study allocated 82.4% to biodiesel and 17.6% to crude glycerin. However, modern plants have biodiesel to crude glycerin ratios of about 10:1 by weight (da Silva et al., 2009; Thompson and He, 2006; Van Gerpen et al., 2006). The model in this study uses output rates of 4,256.3 kg h^{-1} for biodiesel and 479 kg h^{-1} for crude glycerin. This corresponds to a ratio of 89.9% biodiesel to 10.1% crude glycerin, which is close to the modern industrial average. The co-product share of crude glycerin was deducted from the estimated GHG emissions of soybean agriculture, soybean transport, and oil recovery. The overall allocation for soybean agriculture, soybean transport, and oil recovery was therefore 18.4% (20.5% × 89.9%), as shown in table 2.

Results and Discussion

The average soybean yield was 2,907 kg ha^{-1} (43.2 bu ac^{-1}) in 2006 (NASS, 2010). With 0.189 kg oil kg^{-1} soybean and 96% conversion efficiency from oil to biodiesel by weight, each hectare of soybean production is equivalent to 598.7 L of biodiesel (64.12 gal BD ac^{-1}). Biodiesel has a lower heating value (LHV) of 32.7 MJ L^{-1} (Sheehan et al., 1998).

The gCO_2e values from table 1 were converted to consistent units of gCO_2e per GJ of biodiesel output (table 2). The conversion used was 1 ha of soybean production is equivalent to 19,563.3 MJ of energy from biodiesel.

The reduction in GHG emission (81.2%) compared to the reduction reported by NREL (78.5%) was mainly because of improved agricultural management practices and increased energy efficiency in soybean crushing. Since the time of the NREL study, soybean yield has consistently im-

ED_000313_O365_00002632

proved due to genetically engineered varieties, improved chemical applications, and new management practices (Ash et al., 2006). For example, in conjunction with reduced chemical applications and improvements in management practices, fewer equipment trips across the fields are required. Largely as a result of this, diesel fuel use decreased from 49.4 L ha^{-1} (5.29 gal ac^{-1}) in 1990 to 33.3 L ha^{-1} in 2006, and gasoline use decreased from 29.0 to 12.8 L ha^{-1} during the same period. In addition, recently constructed soybean crushing facilities are more energy efficient than older facilities. For instance, since 2002, the U.S. EPA has required soybean plants to limit their hexane use (EPA, 2001). Currently acceptable levels of hexane loss are less than one-third of the level reported in the NREL study (Woerfel, 1995). As a consequence, the new hexane input value used in this study is one-half of that reported in the NREL study.

Effect of Adding Agricultural Lime

The NREL study did not consider the impact of agricultural lime usage on GHG production. Lime is added periodically to reduce soil acidity and to increase soybean yield. The average lime application for soybean production for crop year 2006 was 463.7 kg ha^{-1} (NASS, 2007). With 0.6 $gCO_2e\ g^{-1}$ applied lime ($CaCO_3$) (ANL, 2010), the CO_2 emission associated with lime use was estimated to be 278,220.0 $gCO_2e\ ha^{-1}$. The GHG emission for lime was mainly from mining and processing. Of all agricultural inputs, lime contributed the most GHG. In fact, the emission from lime was 50.6% of the total GHG from agriculture inputs and 2.5 times more than the emission from diesel use, the next largest source of GHG emissions from agricultural inputs. Therefore, lime adds a significant amount of GHG emission to the soybean biodiesel life cycle assessment. The inclusion of lime was also recommended by Landis et al. (2007). The main reason for this high emission from lime is that the quantity of lime applied is significantly higher than other inputs (table 1). If agricultural lime was not included, for a more direct comparison to the NREL report, then the GHG reduction from the use of biodiesel relative to petroleum diesel would have been 84.1%, compared to the 81.2% value in table 2.

Effect of Adding N_2O Emissions from Soils

The NREL estimate did not include soil N_2O emissions. N_2O emissions accounted for 18.0% of total GHG emission from soybean agriculture (emission from agricultural inputs plus soil N_2O). If soil N_2O emissions were not included in the base case study, then the reduction in GHG emission from the use of biodiesel would have been 82.5% rather than 81.2%. The soil N_2O emissions contribute 6.7% of total life cycle GHG emissions for biodiesel production, and hence cannot be neglected. If both lime and N_2O emission were excluded from the life cycle inventory, for a direct comparison with the NREL results, then the GHG reduction for biodiesel relative to petroleum diesel would have been 85.4%, compared to 78.5% reported in the NREL study.

Effect of Adding Soybean Oil Transport

The base case estimation did not include emissions associated with soybean oil transport because this study assumed that the soybean crushing facility and biodiesel conversion plant were co-located. However, several biodiesel plants purchase oil and transport it to their plant. The NREL study included oil transport in its life cycle inventory, which added 560.9 $gCO_2e\ GJ^{-1}$ BD for 919 km (571 mi) using rail as a mode of transportation. This is equivalent to 61.0 $gCO_2e\ GJ^{-1}$ BD for 100 km of oil transport. This is only 1% of the emissions for biodiesel conversion. Thus, if oil transport from the crushing site to the biodiesel production site is a short distance, then emissions from oil transport can be neglected without causing much error.

Effect of Land Use Change (LUC)

In addition to direct emissions, the 2007 EISA requires that calculations of life cycle GHG emissions include all significant indirect emissions, such as significant emissions from indirect land use changes (ILUC). The LUC estimates (both direct and indirect) used by the EPA include domestic and international land use conversions induced by increased consumption of renewable fuels in the U.S. A summary of the EPA calculations for GHG emissions from LUC is shown in table 3.

International land use change is land use change in all countries other than the U.S. How land is used is assumed to be determined by the relative profits from various activities. The EPA estimated the land use change impact with a 30-year horizon beyond the year 2022, when RFS2 is fully implemented, with a 0% discount rate for its rulemaking (EPA, 2010c). A 0% discount rate means that the GHG emissions today are worth the same as emissions 30 years from now. To calculate the annual land use change impact for the next 30 years, an emission average was calculated using the following equation:

$$LUC\_GHG = \frac{\sum_{n=0}^{29} LUC_n}{30} \qquad (1)$$

where LUC_GHG is the annual GHG per GJ of biodiesel, and LUC_n is the GHG emission due to land use change in the nth year. Year 0 in equation 1 is the year 2022. The LUC_GHG value estimated from this equation using data

Table 3. Summary calculation of annual life cycle GHG emission from LUC for the year 2022 and beyond (Source: EPA, 2010b).

	Emission ($gCO_2e\ GJ^{-1}$ Biodiesel)[a]		
Emission Category	Year 0	Years 1-19	Years 20-99
International land use change	1,114,419	5,078	-114
Domestic soil carbon[b]	-252,977	0	0
Domestic livestock	-1,991	-1,991	-1,991
Domestic rice methane	-7,536	-7,536	-7,536
International farm inputs and fert. N_2O	5,120	5,120	5,120
International livestock	-6,100	-6,100	-6,100
International rice methane	2,066	2,066	2,066
Total	853,001	-3,363	-8,555

[a] The conversion factor 1 GJ = 0.948 mmBtu was used to convert to $gCO_2e\ GJ^{-1}$ biodiesel from the original EPA calculations.

[b] Average domestic soil carbon was used for years 1-19 and 20-99.

from table 3 is 23,452 $gCO_2e\ GJ^{-1}$ biodiesel. The EPA assumed that LUC_GHG in equation 1 is caused solely by the shift in the equilibrium of demand for soybean oil and that no allocation of land use change GHG to the co-products is needed (EPA, 2010e). In other words, increased demand for oil is the only driving force in shifting the equilibrium. This assumption is based on the economic principle that assumes when oil price goes up, more soybeans will be crushed, thus increasing the oil supply, and as a result, the supply of meal also increases. With a static demand for meal, as supply increases, the meal price would go down, in which case, it could be argued that the meal is not a driving factor in LUC. Contrary to this assumption, the recent price trend data for soybean meal and oil show that they both go up simultaneously.

The USDA-ERS price data for oil and meal over the past ten years were regressed. The prices of oil and meal had a statistically significant positive correlation, with $R^2 = 0.73$ ($p < 0.0018$) (fig. 1). Another source (IndexMundi, 2012) of historical monthly commodity price data showed that soybean oil and soybean meal prices had a positive correlation, with $R^2 = 0.80$ ($p < 0.0001$) for the period 2002 to 2012. Soybean prices also increased during the same period. The soybean meal price could have increased just because of the higher soybean prices, and the correlation we observed could thus have been just an artifact of an increasing soybean price. To test if this was the case, a relative increase in oil price was compared to a relative increase in meal price. It is important to compare the relative increases in price, as oil has a much higher price per unit of mass compared to meal. For a relative comparison, the prices of oil, meal, and soybean were normalized using equation 2:

$$\text{Normalized price} = \frac{\text{Price} - \text{Minimum price}}{\text{Maximum price} - \text{Minimum price}} \quad (2)$$

Equation 2 linearly scales the prices of oil, meal, and soybean between 0 and 1. The normalized prices for oil and meal were regressed with the normalized price of soybeans using equations 3 and 4:

$$\text{Normalized oil price} = a_1 + b_1 \times \text{Normalized soybean price} \quad (3)$$

$$\text{Normalized meal price} = a_2 + b_2 \times \text{Normalized soybean price} \quad (4)$$

The slopes of the linear lines (b_1 and b_2) represent the relative increase in the price of oil or meal compared to the price of soybeans. The regression analysis showed $b_1 = 0.94$ and $b_2 = 1.00$. This result tells us that the oil price increased by only 94 cents per dollar increase in the soybean price, whereas the meal price increased dollar per dollar with the soybean price. Since the slope of the normalized meal price (b_2) was greater than the slope of the normalized oil price, it was concluded that the relative price of meal was increasing at least as rapidly as the price of oil.

A strong positive correlation between meal and oil indicates that demand for meal and oil increase proportionally. From these results, it was concluded that the price of soybean meal is as strong an incentive to trigger LUC as soybean oil. If price is the driving force, then both meal and oil are the drivers for LUC. In the EPA analysis, the system was expanded to include soybean meal in the partial equilibrium model, which assumes constant meal use. The assumption of constant meal use effectively allocates all LUC emissions to soybean oil, as the model assumes that soybean oil is the only driving factor for LUC.

The strong positive correlation between oil and meal price shows that both co-products act together as a unified driving force in any resulting LUC impact. The extent to which meal should be held accountable for indirect land use change depends on the correlation between meal and oil prices. If there were no positive correlation, then oil price increases alone could be blamed for all indirect land use change, and all LUC_GHG could be attributed to oil, as was done in the EPA study (EPA, 2010d). However, since there is a statistically significant positive correlation between oil and meal prices, the LUC_GHG effects should be allocated to both meal and oil. Thus, equation 1 becomes:

$$LUC\_GHG = \frac{\sum_{n=0}^{29} LUC_n}{30} \times \text{Allocation factor} \quad (5)$$

where the allocation factor partitions the GHG impact to its meal and oil sources. This equation takes into account the fact that both soybean meal and oil are responsible for LUC_GHG, and it attempts to identify the proportion of this value that is attributable to soybean oil production. Assuming the same soybean oil allocation factor for indirect land use change that was applied for soybean agriculture (18.4%), the LUC_GHG was estimated to be 4,315 $gCO_2e\ GJ^{-1}$ BD (instead of the value of 23,452 $gCO_2e\ GJ^{-1}$ in the absence of allocation).

The reduction in GHG emissions from the use of biodiesel, compared to 2005 baseline diesel, was 76.4% after inclusion of LUC (compared to 81.2% before inclusion). The GHG reduction of 76.4% was significantly greater than

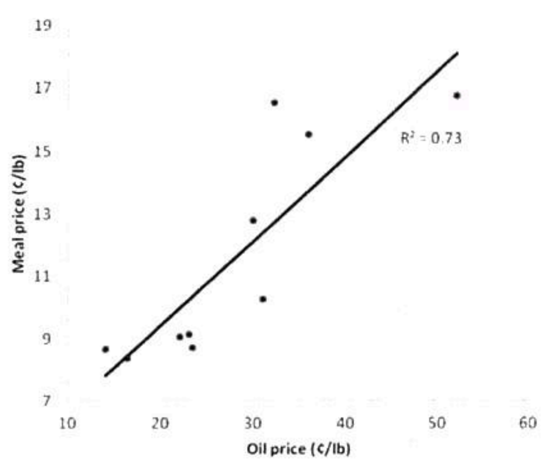

Figure 1. Annual average price of soybean oil and meal from 2000 to 2009 (source: ERS, 2011).

the 57% reduction reported by the EPA in its RFS2 rule-making (EPA, 2010c). The difference arises from the application of the allocation factor to partition GHG impact between oil and meal. The EPA report assigned an allocation factor of 100% to soybean oil and hence to biodiesel. That is, the total GHG impact of land use change was attributed only to biofuel. If a similar assumption is made in this study, then the GHG reduction is estimated to be 55.0% which is close to the value of 57% that was reported by the EPA.

Summary and Conclusions

Using the most recent set of agricultural data available, from the 2006 crop year, soybean biodiesel production and usage were calculated to result in an 81.2% reduction of GHG emissions relative to those calculated for petroleum diesel usage based on 2005 data. This calculation incorporated agricultural lime application and soil N_2O emissions. If lime and N_2O were not included, for a more direct comparison with the 1998 NREL study, the reduction would have been 85.4%. This is a significant improvement over the 1998 NREL study, which reported a total GHG reduction of 78.5%. The improvement in GHG emission reductions was mainly due to reduced agricultural energy usage and improved energy efficiency in modern soybean crushing facilities.

The base case in this study used a similar system boundary as the 1998 NREL study, except that agricultural lime use and soil N_2O emissions were added, and soybean oil transport was omitted. Lime contributed about 50% of the total GHG emissions from soybean agriculture. The GHG emission from lime use was about 2.5 times higher than that of diesel use, the second highest contributor of GHG emissions from agricultural inputs. The emission from soil N_2O was about 18.0% of total emissions from agricultural and 6.7% of the total biodiesel life cycle GHG emissions. Therefore, it was concluded that soil N_2O emissions are significant and cannot be neglected. The impacts of oil transport were excluded from the base case in this study because most biodiesel plants are co-located with oil crushing facilities. The analysis revealed that GHG emission from oil transport of 100 km was equivalent to only 1% of the GHG emission from transesterification. Therefore, the GHG emission from oil transport for short distances could be neglected without causing much error in the final result.

Because soybean oil prices had a strong positive correlation with meal prices, it was argued that both meal and oil prices are responsible for shifting the equilibrium of soybean demand. Holding only soybean oil responsible for land use changes, with the assumption that soybean meal price does not change or decrease because of increased meal supply, was found to be erroneous. When the emissions associated with land use change (direct and indirect) were incorporated into the base case results, the net GHG reduction from biodiesel use was found to be 76.4% less than the emissions for 2005 baseline diesel.

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DRAFT Staff Summary:
Mixed Feedstock for Renewable Diesel
Method 2B Pathway
Diamond Green Diesel

Plant Summary

Diamond Green Diesel (DGD) has submitted a Method 2B application for the production of mixed-feedstock renewable diesel (RD) at its St. Charles, Louisiana plant. The St. Charles plant, which is currently under construction, will be capable of producing 420,000 gallons of RD per day. DGD expects the plant to begin producing RD from the following seven feedstocks in early 2013: Midwestern soy oil, Midwestern corn oil, Midwestern used cooking oil (cooking required), Midwestern used cooking oil (no cooking), U.S. animal fat (higher energy), and U.S. animal fat (lower energy). All seven of DGD's pathways are modified versions of existing LCFS RD or biodiesel pathways. All are modeled as UOP Econofining Processes and utilize the default RD process energy consumption values found in CA-GREET 1.8b. Those process energy defaults are summarized in Table 1 below. All individual feedstocks present in the feedstock mixtures to be run at the St. Charles plant will be tracked by an inventory management system that is integrated into the plant's accounting system. The carbon intensity of all gallons of RD produced will be labeled with the CI of individual feedstocks, in keeping with the mixed-feedstock bio-and renewable diesel guidance published by ARB[1].

Table 1: Energy for Renewable Diesel Process from CA-GREET model

Feedstock	Process Energy Input (Btu/lb)	Electricity and Thermal Energy Shares (%Electric/%Thermal)
Soy Oil	1,851	61.4% / 38.6%
Corn Oil		
Used Cooking Oil (UCO)	2,175	
Tallow		

Operating Conditions

Method 2 applications covering operating plants must base CI calculations on operational data covering two years, whenever possible. Because the DGD application covers a plant that is not yet operational, DGD will submit energy consumption data for the first two years of operation. Data submission will occur no less frequently than annually. If the data submitted indicates that any of DGD's actual production CIs are significantly higher than its approved LCFS pathway CIs, those CIs will be adjusted to better reflect actual operating conditions.

[1] Air Resources Board, December 3, 2012. "Mixed-Feedstock Bio- and Renewable Diesel Guidance." http://www.arb.ca.gov/fuels/lcfs/2a2b/2a-2b-apps.htm.

As a condition of approval, DGD agrees to make all approved pathway CIs available via the LCFS Method 1 Lookup Tables to other RD producers whose production pathways are accurately described by the approved pathways developed in the DGD application.

Carbon Intensity of the Fuel Produced

Because all of DGD's pathway CIs are either higher than the corresponding reference pathways in the LCFS Method 1 Lookup table, or modified versions of LCFS renewable diesel pathways, its application falls under the Method 2B provisions of the LCFS. Method 2B applications are not subject to the substantiality requirements with which Method 2A applications must comply (a minimum improvement of five gCO_2e/MJ, and a minimum production volume of ten million gallons per year).

The proposed DGD pathway CIs are summarized in Table 2.

Table 2: Proposed Lookup Table Entry

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity in gCO_2e/MJ (Including Indirect Effects)		
			Direct Emission	Land Use or Other Indirect Effect	Total
Renewable Diesel	RNWD 010	Conversion of Midwest soybean to renewable diesel (rail transport)	21.70	62	83.70
	RNWD 011	Conversion of Midwest soybean to soy oil to renewable diesel (ship transport)	21.48	62	83.48
	RNWD 012	Renewable diesel from Midwest corn oil produced from Dry DGS (rail transport)	6.00	0	6.00
	RNWD 013	Renewable diesel from Midwest corn oil produced from Dry DGS (ship transport)	5.56	0	5.56
	RNWD 016	Conversion of waste oils (Used Cooking Oil) from Midwest to renewable diesel where "cooking" is required (rail transport)	18.40	0	18.40
	RNWD 017	Conversion of waste oils (Used Cooking Oil) from Midwest to renewable diesel where "cooking" is required (ship transport)	18.18	0	18.18
	RNWD 018	Conversion of waste oils (Used Cooking Oil) from Midwest to renewable diesel where "cooking" is not required (rail transport)	13.85	0	13.85

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity in gCO_2e/MJ (Including Indirect Effects)		
	RNWD 019	Conversion of waste oils (Used Cooking Oil) from Midwest to renewable diesel where "cooking" is not required (ship transport)	13.63	0	13.63
	RNWD 020	Conversion of U.S. tallow to renewable diesel using higher energy use for rendering (rail transport)	40.34	0	40.34
	RNWD 021	Conversion of U.S. tallow to renewable diesel using higher energy use for rendering (ship transport)	40.12	0	40.12
	RNWD 022	Conversion of U.S. tallow to renewable diesel using lower energy use for rendering (rail transport)	19.91	0	19.91
	RNWD 023	Conversion of U.S. tallow to renewable diesel using lower energy use for rendering (ship transport)	19.70	0	19.70

Staff Analysis and Recommendation

Staff has reviewed DGD's application, and finds the following:

- Staff has replicated, using the CA-GREET spreadsheet, the carbon intensity values calculated by DGD; and
- Staff has confirmed that the energy consumption values used in the DGD application are the CA-GREET 1.8b defaults

On the basis of these findings, staff recommends that DGD's Method 2B pathways be approved for use in DGD's mixed-feedstock RD plant.

Biodiesel Profitability

Overview and Assumptions – Overview of the model, assumptions and data sources.

Economic Facility Model – The economic model that computes the monthly costs, revenue and profit (loss).

To navigate among the pages in thi workbook, use the tabs at the botto of the page or the links in the text o this page.

Tables:

Costs and Returns – Monthly Results per Gallon of Biodiesel
Costs and Returns – Monthly Results per Pound of Soybean Oil

Charts:

Input and Output Prices – Monthly biodiesel and glycerine prices -- 2007 to present.
Biodiesel Revenue – Monthly biodiesel and glycerine revenue – 2007 to present
Biodiesel Costs – Monthly cost to produce biodiesel per gallon (total and divided by category) – 2007 to present.
Biodiesel Revenue, Costs and Profits – Monthly costs and returns per gallon – 2007 to present.
Return on Equity – Monthly percent return on equity --- 2007 to present.
Breakeven Purchase Cost for Soybean oil and Sale Price for Biodiesel – Monthly prices facility can pay for soybean oil and receive for biodiesel just to cover costs -- 2007 to present.
Biodiesel Revenue, Variable Costs and Profits – Monthly variable costs and returns per gallon – 2007 to present.

Ag Marketing Resource Center, Biodiesel Profitability
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Overview and Assumptions of Biodiesel Profitability

The profitability of biodiesel production is extremely variable. Due to the volatile price nature of biodiesel and soybean oil, its major feedstock, biodiesel profitability can change rapidly from month to month. In addition, price variations of its co-product (glycerine) and its energy source (natural gas) add to the variability of biodiesel profits.

To track the profitability of biodiesel production, an economic model of a typical Iowa biodiesel plant was created. This is a 30 million gallon facility with construction costs similar to plants built in 2007. The costs and efficiencies are believed to be typical of Iowa biodiesel plants. The prices of biodiesel, glycerine, soybean oil and natural gas are updated monthly to compute the current profitability of biodiesel production.

Monthly price variables

1) **Biodiesel Price** – Weekly price F.O.B (Free on Board) the plant (converted into monthly average prices) as reported in the National Weekly Ag Energy Round-up by the USDA Ag Marketing Service.

2) **Soybean Oil Price** – Daily price converted into monthly average prices as reported by the USDA Ag Market Research Service, Iowa Soybean Processors Report.

3) **Methanol Price** – Monthly Average Regional Posted Contract Price History reported by Methanex.

4) **Natural Gas Price** – Monthly Iowa natural gas price for industrial users as reported by the Energy Information Administration (official energy statistics of the U.S. government).

Although these prices are representative of Iowa biodiesel plants, they may not be representative of plants in other regions or states. In the economic model the user can increase or decrease any of the price series by a fixed amount to represent a special situation. An adjustment in a price series will be reflected in the analysis tables and graphs.

Revenue, costs and net returns (profitability) are shown monthly per gallon of biodiesel and per 100 pounds of soybean oil. Also, biodiesel and soy oil price breakeven levels are computed.

Major assumptions and characteristics of the biodiesel plant model

1) Turnkey biodiesel production facility
2) Facility built in 2007
3) Nameplate capacity of 30 million gallons
4) Facility construction cost (including working capital) of $1.57 per gallon of nameplate capacity
5) Lender finances 50 percent of the project
6) Equity financing of 50 percent of the project
7) Plant operates at 100 percent of nameplate capacity
8) Conversion factor of 7.55 pounds of soybean oil per gallon of biodiesel
9) A gallon of biodiesel produces .9 pounds of glycerine
10) Natural gas requirement of 7 cubic feet per gallon of biodiesel
11) Typical input costs for an Iowa soybean oil biodiesel facility

The monthly profitability of this hypothetical plant is computed by using the monthly market prices for biodiesel, soybean oil, methanol and natural gas. Each month the analysis is updated with the previous month's prices. If any of these price data series do not fit your situation, you can enter an adjustment factor that will increase or decrease the coefficients in the price data series. All other variables are held constant throughout the analysis.

Input coefficient adjustment. Although we believe the coefficients in this model are a good representation of a soybean oil biodiesel plant, the user has the ability to change any of the input coefficients in the economic model to fit a special situation. A change in an input coefficient will be reflected in the analysis tables and graphs.

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2634

Economic Model of a Biodiesel Production Facility

Place the cursor over cells with red triangles to read comments.

Assumptions (inputs)

Facility Construction

Nameplate Capacity	30,000,000	gal./yr.
Organizational Costs	$200,000	
Process System	$30,000,000	
Land, Site and Other	$7,400,000	
Construction Related Costs	$2,500,000	
Office and Administration	$900,000	
Inventory & Working Capital	$6,000,000	
Estimated Life	15	years
Property Taxes	$50,000	per yr.

Financing

Percent Debt	50	%
Length of Loan	10	years
Interest Rate	8.25	%

Efficiency Factors

Soybean Oil	7.55	lbs./gal. biodiesel
Production Level	100	% capacity
Glycerine	0.90	lbs./gal. biodiesel
Methanol	0.71	lbs./gal. biodiesel
Natural Gas	7	cub. ft./gal. biodiesel
Electricity	0.6	Kwh./gal. biodiesel
Water	2.0	gal./gal. biodiesel

Chemicals

Chemicals and Ingredients	5.70	¢/gallon

Prices

Electricity	5.000	¢/KwH
Water	0.350	¢/gallon
Glycerin	3.000	¢/pound

Labor & Management

	Number	Salary
Operations	12	$68,000
Maintenance	2	$72,000
Laboratory	1	$80,000
Material Handlers	10	$30,000
Administration	3	$90,000
Total	28	$1,610,000

Other Direct Costs

Repairs & Maintenance	3.00	¢/gallon
Transportation	10.00	¢/gallon
Marketing and Procurement	4.00	¢/gallon
Other	3.00	¢/gallon

Price Adjustments (+ or -)

Biodiesel	$0.00	$/gallon
Soybean Oil	0.00	¢/gallon
Natural Gas	$0.00	$/1000 cubic feet

Output

Annual Production and Resource Usage

Construction Cost		
Total	$47,000,000	
Equity	$23,500,000	
Debt	$23,500,000	
Per Gal. Nameplate Capacity	$1.57	
Per Gal. Operating Capacity	$1.57	
Per Lb. Soybean Oil Oper. Cap.	$0.21	
Depreciation	$2,733,333	per year
Biodiesel Production		
Nameplate Capacity	30,000,000	gallons per year
Operating Capacity	30,000,000	gallons per year
Glycerine Production	27,000,000	pounds per year
Soybean Oil Usage	226,500,000	pounds per year
Natural Gas Usage	210,000	1,000 cubic feet/year
Electricity Usage	18,000,000	kilowatt hours/year
Electricity Cost	$900,000	per year
Water Usage	60,000,000	gallons per year
Water Cost	$210,000	per year
Number of Employees	28	employees
Labor & Management Cost	$1,610,000	per year
Interest Cost	$1,938,750	per year
Chemicals and Ingredients	$1,710,000	per year
Repairs & Maintenance	$200,000	per year
Transportation Cost	$3,000,000	per year
Other Costs	$200,000	per year

Production Costs

	Cost per Gallon	Cost per Pound
Chemicals		
Chemicals and Ingredients	5.70 ¢/gal.	0.75 ¢/lb.
Total Chemical Cost	**5.70 ¢/gal.**	**0.75 ¢/lb.**
Other Direct Costs		
Repairs & Maintenance	3.00 ¢/gal.	0.40 ¢/lb.
Transportation	10.00 ¢/gal.	1.32 ¢/lb.
Water	0.70 ¢/gal.	0.09 ¢/lb.
Electricity	3.00 ¢/gal.	0.40 ¢/lb.
Other	3.00 ¢/gal.	0.40 ¢/lb.
Total Other Costs	**19.70 ¢/gal.**	**2.61 ¢/lb.**
Fixed Costs		
Depreciation	9.11 ¢/gal.	1.21 ¢/lb.
Interest	6.46 ¢/gal.	0.86 ¢/lb.
Labor & Management	5.37 ¢/gal.	0.71 ¢/lb.
Marketing & Procurement	4.00 ¢/gal.	0.53 ¢/lb.
Property Taxes, Insurance, etc.	1.17 ¢/gal.	0.15 ¢/lb.
Total Fixed Costs	**26.11 ¢/gal.**	**3.46 ¢/lb.**
Total Costs (less corn & natural gas)		
Total Variable Costs	25.40 ¢/gal.	3.36 ¢/lb.
Total Variable & Fixed Costs	51.51 ¢/gal.	6.82 ¢/lb.

2634

Monthly Costs and Returns per Gallon of Biodiesel Produced

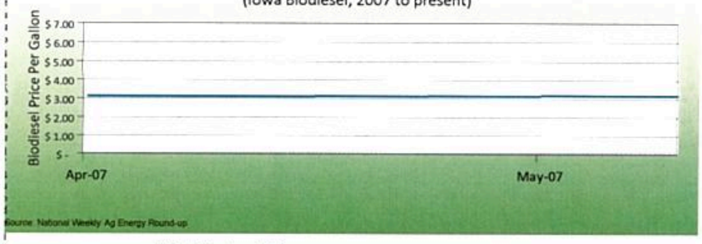
Month and Year	Prices				Revenue per Gallon			Cost per Gallon								Net Return/Gal.	
	Biodiesel (gallon)	Soybean Oil (pound)	Natural Gas (000 cub. ft)	Methanol (pound)	Biodiesel Revenue	Glycerine Revenue	Total Revenue	Soybean Oil Cost	Natural Gas Cost	Methanol Cost	Other Variable Costs	Total Variable Costs	Fixed Costs	Total Cost	Biodiesel Break-even	Over Variable Costs	Over All Costs
Apr-07	$ 3.09	$ 0.30	$ 8.58	$ 0.15	$ 3.09	$ 0.03	$ 3.12	$ 2.26	$ 0.06	$ 0.11	$ 0.25	$ 2.68	$ 0.26	$ 2.94	$ 2.91	$ 0.44	$ 0.18
May-07	$ 3.16	$ 0.32	$ 8.00	$ 0.15	$ 3.16	$ 0.03	$ 3.18	$ 2.43	$ 0.06	$ 0.11	$ 0.25	$ 2.85	$ 0.26	$ 3.11	$ 3.08	$ 0.33	$ 0.07
Jun-07	$ 3.17	$ 0.33	$ 8.58	$ 0.15	$ 3.17	$ 0.03	$ 3.19	$ 2.49	$ 0.06	$ 0.11	$ 0.25	$ 2.91	$ 0.26	$ 3.17	$ 3.15	$ 0.28	$ 0.02
Jul-07	$ 3.20	$ 0.34	$ 8.61	$ 0.14	$ 3.20	$ 0.03	$ 3.22	$ 2.60	$ 0.06	$ 0.10	$ 0.25	$ 3.01	$ 0.26	$ 3.27	$ 3.24	$ 0.21	$ (0.05)
Aug-07	$ 3.22	$ 0.34	$ 7.88	$ 0.14	$ 3.22	$ 0.03	$ 3.25	$ 2.54	$ 0.06	$ 0.10	$ 0.25	$ 2.94	$ 0.26	$ 3.21	$ 3.18	$ 0.30	$ 0.04
Sep-07	$ 3.29	$ 0.37	$ 7.48	$ 0.14	$ 3.29	$ 0.03	$ 3.32	$ 2.77	$ 0.05	$ 0.10	$ 0.25	$ 3.18	$ 0.26	$ 3.44	$ 3.41	$ 0.14	$ (0.12)
Oct-07	$ 3.44	$ 0.38	$ 7.48	$ 0.26	$ 3.44	$ 0.03	$ 3.47	$ 2.87	$ 0.05	$ 0.18	$ 0.25	$ 3.36	$ 0.26	$ 3.62	$ 3.59	$ 0.11	$ (0.15)
Nov-07	$ 3.74	$ 0.43	$ 8.53	$ 0.30	$ 3.74	$ 0.03	$ 3.77	$ 3.24	$ 0.06	$ 0.21	$ 0.25	$ 3.77	$ 0.26	$ 4.03	$ 4.01	$ (0.00)	$ (0.26)
Dec-07	$ 3.92	$ 0.44	$ 8.86	$ 0.38	$ 3.92	$ 0.03	$ 3.95	$ 3.35	$ 0.06	$ 0.27	$ 0.25	$ 3.94	$ 0.26	$ 4.20	$ 4.17	$ 0.01	$ (0.25)
Jan-08	$ 4.28	$ 0.49	$ 8.74	$ 0.38	$ 4.28	$ 0.03	$ 4.30	$ 3.71	$ 0.06	$ 0.27	$ 0.25	$ 4.29	$ 0.26	$ 4.55	$ 4.53	$ 0.01	$ (0.25)
Feb-08	$ 4.68	$ 0.56	$ 9.99	$ 0.32	$ 4.68	$ 0.03	$ 4.70	$ 4.26	$ 0.07	$ 0.22	$ 0.25	$ 4.81	$ 0.26	$ 5.07	$ 5.05	$ (0.11)	$ (0.37)
Mar-08	$ 5.16	$ 0.57	$ 10.06	$ 0.29	$ 5.16	$ 0.03	$ 5.19	$ 4.32	$ 0.07	$ 0.20	$ 0.25	$ 4.85	$ 0.26	$ 5.11	$ 5.08	$ 0.34	$ 0.08
Apr-08	$ 4.98	$ 0.56	$ 10.71	$ 0.24	$ 4.98	$ 0.03	$ 5.01	$ 4.21	$ 0.07	$ 0.17	$ 0.25	$ 4.71	$ 0.26	$ 4.97	$ 4.94	$ 0.30	$ 0.04
May-08	$ 5.26	$ 0.58	$ 10.89	$ 0.23	$ 5.26	$ 0.03	$ 5.28	$ 4.38	$ 0.08	$ 0.16	$ 0.25	$ 4.87	$ 0.26	$ 5.13	$ 5.10	$ 0.42	$ 0.15
Jun-08	$ 5.51	$ 0.62	$ 11.83	$ 0.24	$ 5.51	$ 0.03	$ 5.54	$ 4.65	$ 0.08	$ 0.17	$ 0.25	$ 5.16	$ 0.26	$ 5.42	$ 5.39	$ 0.38	$ 0.12
Jul-08	$ 5.47	$ 0.60	$ 12.42	$ 0.24	$ 5.47	$ 0.03	$ 5.49	$ 4.54	$ 0.09	$ 0.17	$ 0.25	$ 5.05	$ 0.26	$ 5.31	$ 5.28	$ 0.45	$ 0.19
Aug-08	$ 4.88	$ 0.51	$ 11.83	$ 0.24	$ 4.88	$ 0.03	$ 4.90	$ 3.82	$ 0.08	$ 0.17	$ 0.25	$ 4.33	$ 0.26	$ 4.59	$ 4.56	$ 0.57	$ 0.31
Sep-08	$ 4.43	$ 0.46	$ 9.30	$ 0.24	$ 4.43	$ 0.03	$ 4.46	$ 3.44	$ 0.07	$ 0.17	$ 0.25	$ 3.93	$ 0.26	$ 4.19	$ 4.16	$ 0.53	$ 0.27
Oct-08	$ 3.65	$ 0.35	$ 7.30	$ 0.23	$ 3.65	$ 0.03	$ 3.67	$ 2.63	$ 0.05	$ 0.16	$ 0.25	$ 3.10	$ 0.26	$ 3.36	$ 3.33	$ 0.57	$ 0.31
Nov-08	$ 3.19	$ 0.32	$ 7.11	$ 0.21	$ 3.19	$ 0.03	$ 3.22	$ 2.40	$ 0.05	$ 0.15	$ 0.25	$ 2.86	$ 0.26	$ 3.12	$ 3.09	$ 0.36	$ 0.10
Dec-08	$ 2.84	$ 0.29	$ 7.92	$ 0.15	$ 2.84	$ 0.03	$ 2.87	$ 2.17	$ 0.06	$ 0.11	$ 0.25	$ 2.58	$ 0.26	$ 2.84	$ 2.82	$ 0.29	$ 0.03
Jan-09	$ 3.09	$ 0.32	$ 8.22	$ 0.11	$ 3.09	$ 0.03	$ 3.12	$ 2.40	$ 0.06	$ 0.08	$ 0.25	$ 2.78	$ 0.26	$ 3.04	$ 3.02	$ 0.33	$ 0.07
Feb-09	$ 2.82	$ 0.29	$ 7.84	$ 0.11	$ 2.82	$ 0.03	$ 2.85	$ 2.17	$ 0.05	$ 0.08	$ 0.25	$ 2.56	$ 0.26	$ 2.82	$ 2.79	$ 0.29	$ 0.03
Mar-09	$ 2.68	$ 0.28	$ 7.28	$ 0.10	$ 2.68	$ 0.03	$ 2.71	$ 2.12	$ 0.05	$ 0.07	$ 0.25	$ 2.49	$ 0.26	$ 2.76	$ 2.73	$ 0.21	$ (0.05)
Apr-09	$ 2.94	$ 0.33	$ 5.60	$ 0.09	$ 2.94	$ 0.03	$ 2.97	$ 2.47	$ 0.04	$ 0.06	$ 0.25	$ 2.83	$ 0.26	$ 3.09	$ 3.06	$ 0.14	$ (0.12)
May-09	$ 3.10	$ 0.36	$ 4.84	$ 0.09	$ 3.10	$ 0.03	$ 3.13	$ 2.73	$ 0.03	$ 0.06	$ 0.25	$ 3.09	$ 0.26	$ 3.35	$ 3.32	$ 0.04	$ (0.22)
Jun-09	$ 3.13	$ 0.35	$ 4.57	$ 0.09	$ 3.13	$ 0.03	$ 3.16	$ 2.68	$ 0.03	$ 0.06	$ 0.25	$ 3.03	$ 0.26	$ 3.29	$ 3.26	$ 0.13	$ (0.13)
Jul-09	$ 2.86	$ 0.31	$ 4.55	$ 0.10	$ 2.86	$ 0.03	$ 2.89	$ 2.37	$ 0.03	$ 0.07	$ 0.25	$ 2.73	$ 0.26	$ 2.99	$ 2.96	$ 0.16	$ (0.10)
Aug-09	$ 3.11	$ 0.34	$ 4.73	$ 0.11	$ 3.11	$ 0.03	$ 3.13	$ 2.53	$ 0.03	$ 0.08	$ 0.25	$ 2.90	$ 0.26	$ 3.16	$ 3.13	$ 0.24	$ (0.02)
Sep-09	$ 3.02	$ 0.31	$ 4.68	$ 0.13	$ 3.02	$ 0.03	$ 3.04	$ 2.35	$ 0.03	$ 0.09	$ 0.25	$ 2.72	$ 0.26	$ 2.99	$ 2.96	$ 0.32	$ 0.06
Oct-09	$ 3.12	$ 0.34	$ 4.84	$ 0.14	$ 3.12	$ 0.03	$ 3.15	$ 2.54	$ 0.03	$ 0.10	$ 0.25	$ 2.93	$ 0.26	$ 3.19	$ 3.17	$ 0.21	$ (0.05)
Nov-09	$ 3.37	$ 0.37	$ 6.16	$ 0.15	$ 3.37	$ 0.03	$ 3.40	$ 2.76	$ 0.04	$ 0.11	$ 0.25	$ 3.16	$ 0.26	$ 3.42	$ 3.39	$ 0.24	$ (0.02)
Dec-09	$ 3.36	$ 0.37	$ 6.79	$ 0.17	$ 3.36	$ 0.03	$ 3.39	$ 2.79	$ 0.05	$ 0.12	$ 0.25	$ 3.21	$ 0.26	$ 3.48	$ 3.45	$ 0.17	$ (0.09)
Jan-10	$ 3.31	$ 0.36	$ 6.61	$ 0.17	$ 3.31	$ 0.03	$ 3.34	$ 2.68	$ 0.05	$ 0.12	$ 0.25	$ 3.10	$ 0.26	$ 3.36	$ 3.33	$ 0.24	$ (0.03)
Feb-10	$ 3.29	$ 0.35	$ 7.08	$ 0.17	$ 3.29	$ 0.03	$ 3.32	$ 2.67	$ 0.05	$ 0.12	$ 0.25	$ 3.09	$ 0.26	$ 3.35	$ 3.33	$ 0.23	$ (0.03)
Mar-10	$ 3.31	$ 0.36	$ 7.06	$ 0.17	$ 3.31	$ 0.03	$ 3.34	$ 2.75	$ 0.05	$ 0.12	$ 0.25	$ 3.18	$ 0.26	$ 3.44	$ 3.41	$ 0.17	$ (0.10)
Apr-10	$ 3.32	$ 0.36	$ 6.21	$ 0.17	$ 3.32	$ 0.03	$ 3.35	$ 2.74	$ 0.04	$ 0.12	$ 0.25	$ 3.16	$ 0.26	$ 3.42	$ 3.39	$ 0.19	$ (0.07)
May-10	$ 3.23	$ 0.35	$ 5.45	$ 0.15	$ 3.23	$ 0.03	$ 3.26	$ 2.65	$ 0.04	$ 0.11	$ 0.25	$ 3.05	$ 0.26	$ 3.31	$ 3.29	$ 0.21	$ (0.05)
Jun-10	$ 3.17	$ 0.35	$ 5.61	$ 0.16	$ 3.17	$ 0.03	$ 3.20	$ 2.62	$ 0.04	$ 0.11	$ 0.25	$ 3.03	$ 0.26	$ 3.29	$ 3.26	$ 0.17	$ (0.09)
Jul-10	$ 3.18	$ 0.35	$ 5.69	$ 0.16	$ 3.18	$ 0.03	$ 3.21	$ 2.66	$ 0.04	$ 0.11	$ 0.25	$ 3.07	$ 0.26	$ 3.33	$ 3.30	$ 0.14	$ (0.12)
Aug-10	$ 3.30	$ 0.36	$ 5.76	$ 0.16	$ 3.30	$ 0.03	$ 3.33	$ 2.75	$ 0.04	$ 0.11	$ 0.25	$ 3.16	$ 0.26	$ 3.42	$ 3.39	$ 0.17	$ (0.09)
Sep-10	$ 3.35	$ 0.39	$ 5.59	$ 0.16	$ 3.35	$ 0.03	$ 3.38	$ 2.95	$ 0.04	$ 0.12	$ 0.25	$ 3.35	$ 0.26	$ 3.62	$ 3.59	$ 0.02	$ (0.24)

2634

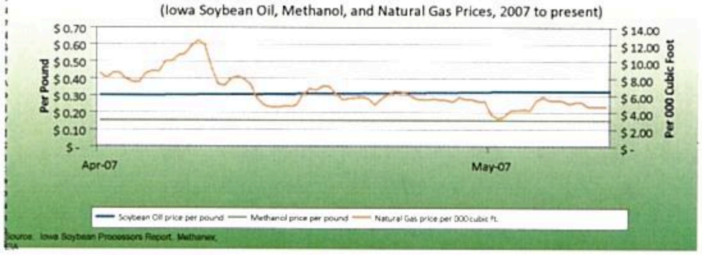
Monthly Biodiesel Costs and Returns per Pound of Soybean Oil Processed

Month and Year	*Prices*				*Revenue per Pound*				*Total Cost/Lb.*			*Net Return/Lb.*		*Return on Equity*
	Biodiesel (per gal.)	Soybean Oil (per lbs.)	Natural Gas (000 cub. ft.)	Methanol (per lbs.)	Biodiesel Revenue	Glycerine Revenue	Total Revenue	Soybean Oil Break-even	Variable Costs	Fixed Costs	Total Costs	Over Variable Costs	Over All Costs	Annual
Apr-07	$ 3.09	$ 0.30	$ 8.58	$ 0.15	$ 0.41	$ 0.00	$ 0.41	$ 0.32	$ 0.35	$ 0.03	$ 0.39	$ 0.06	$ 0.02	23%
May-07	$ 3.16	$ 0.32	$ 8.00	$ 0.15	$ 0.42	$ 0.00	$ 0.42	$ 0.33	$ 0.38	$ 0.03	$ 0.41	$ 0.04	$ 0.01	9%
Jun-07	$ 3.17	$ 0.33	$ 8.58	$ 0.15	$ 0.42	$ 0.00	$ 0.42	$ 0.33	$ 0.39	$ 0.03	$ 0.42	$ 0.04	$ 0.00	2%
Jul-07	$ 3.20	$ 0.34	$ 8.61	$ 0.14	$ 0.42	$ 0.00	$ 0.43	$ 0.34	$ 0.40	$ 0.03	$ 0.43	$ 0.03	$ (0.01)	-6%
Aug-07	$ 3.22	$ 0.34	$ 7.88	$ 0.14	$ 0.43	$ 0.00	$ 0.43	$ 0.34	$ 0.39	$ 0.03	$ 0.42	$ 0.04	$ 0.01	5%
Sep-07	$ 3.29	$ 0.37	$ 7.48	$ 0.14	$ 0.44	$ 0.00	$ 0.44	$ 0.35	$ 0.42	$ 0.03	$ 0.46	$ 0.02	$ (0.02)	-16%
Oct-07	$ 3.44	$ 0.38	$ 7.48	$ 0.26	$ 0.46	$ 0.00	$ 0.46	$ 0.36	$ 0.44	$ 0.03	$ 0.48	$ 0.01	$ (0.02)	-19%
Nov-07	$ 3.74	$ 0.43	$ 8.53	$ 0.30	$ 0.50	$ 0.00	$ 0.50	$ 0.39	$ 0.50	$ 0.03	$ 0.53	$ (0.00)	$ (0.03)	-34%
Dec-07	$ 3.92	$ 0.44	$ 8.86	$ 0.38	$ 0.52	$ 0.00	$ 0.52	$ 0.41	$ 0.52	$ 0.03	$ 0.56	$ 0.00	$ (0.03)	-32%
Jan-08	$ 4.28	$ 0.49	$ 8.74	$ 0.38	$ 0.57	$ 0.00	$ 0.57	$ 0.46	$ 0.57	$ 0.03	$ 0.60	$ 0.00	$ (0.03)	-32%
Feb-08	$ 4.68	$ 0.56	$ 9.99	$ 0.32	$ 0.62	$ 0.00	$ 0.62	$ 0.52	$ 0.64	$ 0.03	$ 0.67	$ (0.01)	$ (0.05)	-47%
Mar-08	$ 5.16	$ 0.57	$ 10.06	$ 0.29	$ 0.68	$ 0.00	$ 0.69	$ 0.58	$ 0.64	$ 0.03	$ 0.68	$ 0.05	$ 0.01	10%
Apr-08	$ 4.98	$ 0.56	$ 10.71	$ 0.24	$ 0.66	$ 0.00	$ 0.66	$ 0.56	$ 0.62	$ 0.03	$ 0.66	$ 0.04	$ 0.00	5%
May-08	$ 5.26	$ 0.58	$ 10.89	$ 0.23	$ 0.70	$ 0.00	$ 0.70	$ 0.60	$ 0.64	$ 0.03	$ 0.68	$ 0.06	$ 0.02	20%
Jun-08	$ 5.51	$ 0.62	$ 11.83	$ 0.24	$ 0.73	$ 0.00	$ 0.73	$ 0.63	$ 0.68	$ 0.03	$ 0.72	$ 0.05	$ 0.02	15%
Jul-08	$ 5.47	$ 0.60	$ 12.42	$ 0.24	$ 0.72	$ 0.00	$ 0.73	$ 0.63	$ 0.67	$ 0.03	$ 0.70	$ 0.06	$ 0.02	24%
Aug-08	$ 4.88	$ 0.51	$ 11.83	$ 0.24	$ 0.65	$ 0.00	$ 0.65	$ 0.55	$ 0.57	$ 0.03	$ 0.61	$ 0.08	$ 0.04	40%
Sep-08	$ 4.43	$ 0.46	$ 9.30	$ 0.24	$ 0.59	$ 0.00	$ 0.59	$ 0.49	$ 0.52	$ 0.03	$ 0.55	$ 0.07	$ 0.04	35%
Oct-08	$ 3.65	$ 0.35	$ 7.30	$ 0.23	$ 0.48	$ 0.00	$ 0.49	$ 0.39	$ 0.41	$ 0.03	$ 0.44	$ 0.08	$ 0.04	40%
Nov-08	$ 3.19	$ 0.32	$ 7.11	$ 0.21	$ 0.42	$ 0.00	$ 0.43	$ 0.33	$ 0.38	$ 0.03	$ 0.41	$ 0.05	$ 0.01	13%
Dec-08	$ 2.84	$ 0.29	$ 7.92	$ 0.15	$ 0.38	$ 0.00	$ 0.38	$ 0.29	$ 0.34	$ 0.03	$ 0.38	$ 0.04	$ 0.00	3%
Jan-09	$ 3.09	$ 0.32	$ 8.22	$ 0.11	$ 0.41	$ 0.00	$ 0.41	$ 0.33	$ 0.37	$ 0.03	$ 0.40	$ 0.04	$ 0.01	9%
Feb-09	$ 2.82	$ 0.29	$ 7.84	$ 0.11	$ 0.37	$ 0.00	$ 0.38	$ 0.29	$ 0.34	$ 0.03	$ 0.37	$ 0.04	$ 0.00	4%
Mar-09	$ 2.68	$ 0.28	$ 7.28	$ 0.10	$ 0.36	$ 0.00	$ 0.36	$ 0.27	$ 0.33	$ 0.03	$ 0.36	$ 0.03	$ (0.01)	-6%
Apr-09	$ 2.94	$ 0.33	$ 5.60	$ 0.09	$ 0.39	$ 0.00	$ 0.39	$ 0.31	$ 0.37	$ 0.03	$ 0.41	$ 0.02	$ (0.02)	-16%

Monthly Biodiesel Price per Gallon
(Iowa Biodiesel, 2007 to present)

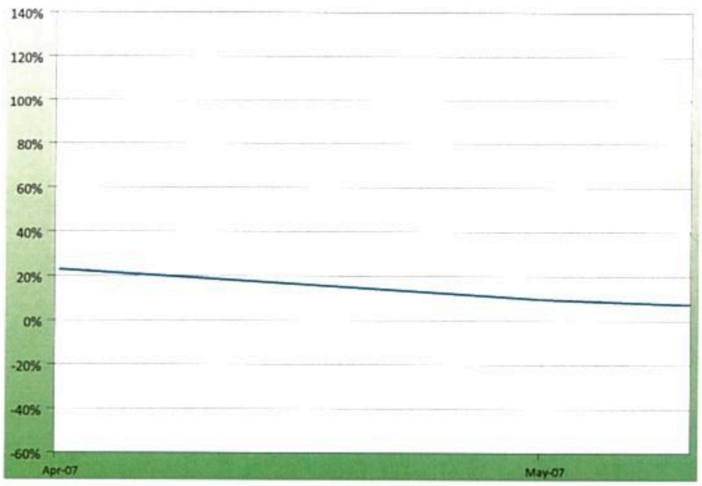


Monthly Input Prices
(Iowa Soybean Oil, Methanol, and Natural Gas Prices, 2007 to present)



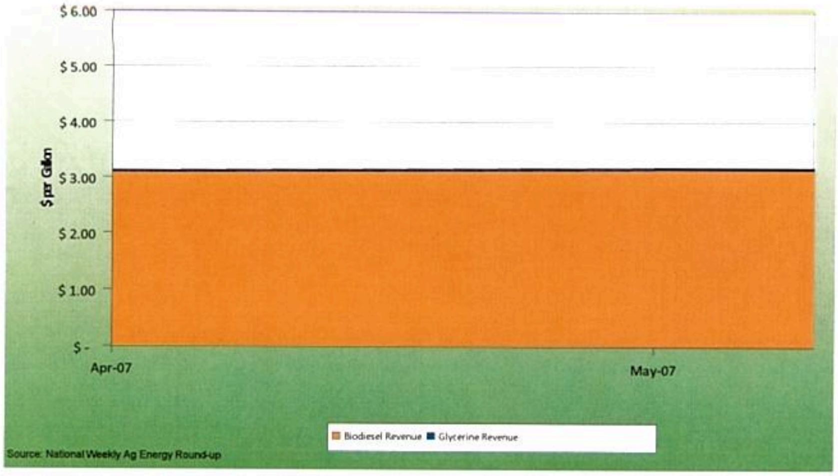
2634

Percent Return on Equity
(annualized basis) (2007 to present)



2634

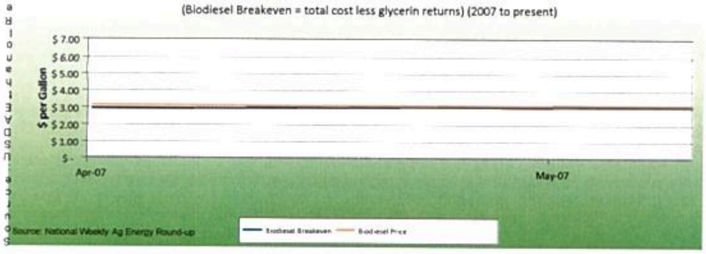
Total Revenue per Gallon
(biodiesel, glycerine and total, 2007 to present)



2634

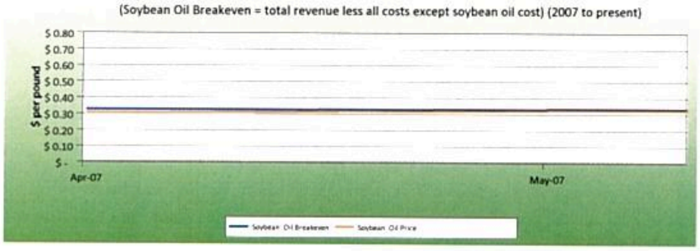
Biodiesel Breakeven and Biodiesel Price

(Biodiesel Breakeven = total cost less glycerin returns) (2007 to present)

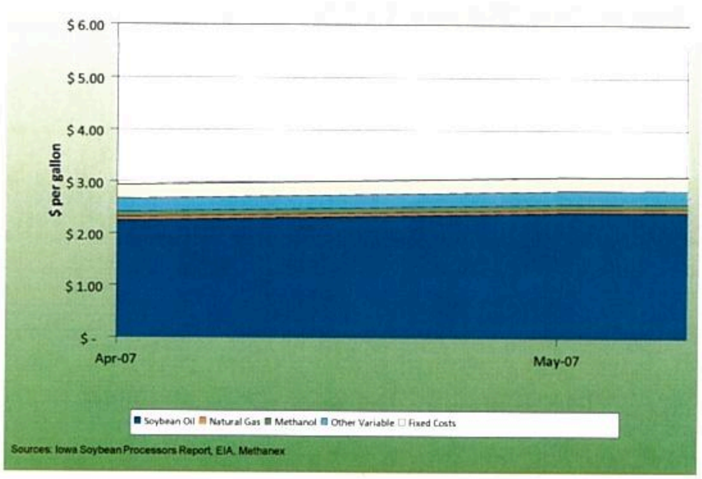


Soybean Oil Breakeven and Market Price

(Soybean Oil Breakeven = total revenue less all costs except soybean oil cost) (2007 to present)

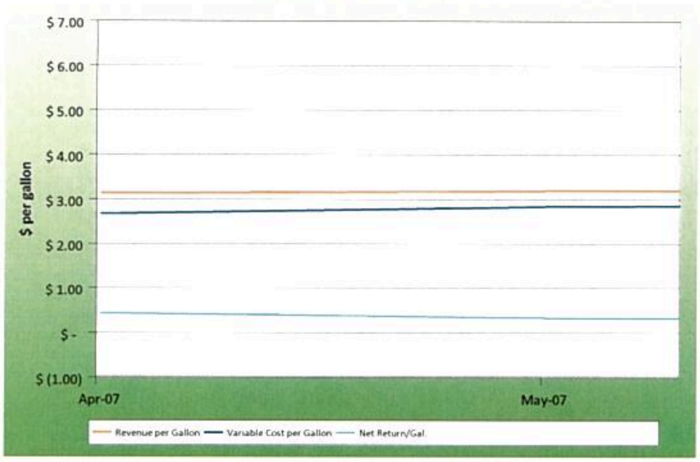


Cost of Biodiesel Production
($/gallon) (2007 to present)

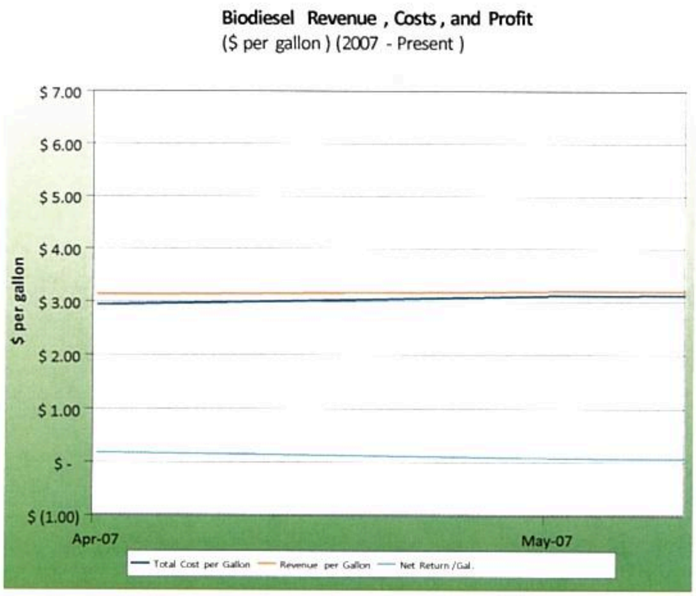


2634

Biodiesel Revenue, Variable Cost, and Return Over Variable Cost
($ per gallon) (2007 - Present)



2634


Biodiesel Revenue , Costs , and Profit
($ per gallon) (2007 - Present)
$ 7.00
$ 6.00
$ 5.00
$ 4.00
$ 3.00
$ 2.00
$ 1.00
$ -
$ (1.00)
$ per gallon
Apr-07
May-07
Total Cost per Gallon
Revenue per Gallon
Net Return /Gal.

2634

Friday,
March 26, 2010

Book 2 of 2 Books
Pages 14669–15320

Federal Register

Part II

Environmental Protection Agency

40 CFR Part 80

Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule

Attachment 2010-3851.pdf
Public Document

ED_000313_O365_00002635

biodiesel (billion gallons)	Feedstock Usage (22M data)	2013 feedstock % of industry production (22M data)	LCA Source	% GHG reduction	Feedstock (LCA category)	Diesel Baseline emissions gCO2e/MJ	Biodiesel Carbon Intensity gCO2e/MJ	Biodiesel lb CO2e/125,000 BTU	GHG reduction in lbs CO2e/gallon of biodiesel	GHG reduction in billion lbs CO2e	GHG reduction in million tons CO2e	GHG reduction in million Metric tons CO2e
1.7	soy	48%	USEPA 2010	57.0%	soy	89.7	38.6	11.2	14.1	23.9	11.9	10.8
1.7	corn oil	10%	USEPA 2010	86.0%	waste grease	89.7	12.6	3.7	21.2	36.0	18.0	16.4
1.7	used cooking oil	8%	USEPA 2010	86.0%	waste grease	89.7	12.6	3.7				
1.7	other recycled grease	3%	USEPA 2010	86.0%	waste grease	89.7	12.6	3.7				
1.7	animal fat	11%	USEPA 2010	86.0%	waste grease	89.7	12.6	3.7				
1.7	renewable diesel	15%	USEPA 2010	86.0%	waste grease	89.7	12.6	3.7				
1.7	canola	5%	USEPA 2010	50.5%	canola	89.7	44.4	12.9	12.5	21.2	10.6	9.6
1.7		100%	**USEPA 2010 weighted by 2013 industry production**	70.3%	**2013 industry r**	89.7	26.6	7.7	17.3	29.5	14.7	13.4
1.7			USDA/Idaho 2012	76.4%	soy	89.7	21.2	6.2	18.8	32.0	16.0	14.5
1.7	soy	48%	USDA/Idaho 2012	77.9%	soy	96	21.2	6.2	20.6	35.0	17.5	15.9
1.7	corn oil	10%	CARB 2011	95.8%	corn oil	96	4.0	1.2	25.3	43.0	21.5	19.5
1.7	used cooking oil	8%	USEPA 2010	86.9%	waste grease	96	12.6	3.7	22.9	39.0	19.5	17.7
1.7	other recycled grease	3%	USEPA 2010	86.9%	waste grease	96	12.6	3.7				
1.7	animal fat	11%	USEPA 2010	86.9%	waste grease	96	12.6	3.7				
1.7	renewable diesel	15%	CARB 2011	79.5%	tallow RD	96	19.7	5.7	21.0	35.7	17.8	16.2
1.7	canola	5%	USEPA 2010	53.7%	canola	96	44.4	12.9	14.2	24.1	12.1	10.9
1.7			**best available data weighted by 2013 industry production**	80.7%	**2013 industry r**	96	18.5	5.4	21.3	36.2	18.1	16.4

green = inputs can be changed
inputs from reference material
calculated by table

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Input		Unit	2011	2012	2013
Feedstock Inputs					
Feedstock Breakdown	Canola Oil	%	12%	11%	5%
	Distillers Corn Oil	%	4%	8%	10%
	Soybean Oil	%	55%	52%	48%
	Animal Fats	%	16%	13%	11%
	Yellow Grease	%	9%	9%	11%
	Renewable Diesel	%	4%	8%	15%
Cost of Feedstocks	Canola Oil	cents/pound	61.0	61.2	56.2
	Distillers Corn Oil	cents/pound	43.6	38.0	34.6
	Soybean Oil	cents/pound	54.1	51.7	47.9
	Animal Fats	cents/pound	47.1	42.5	38.6
	Yellow Grease	cents/pound	43.1	37.3	34.5
	Renewable Diesel	cents/pound	45.1	39.9	35.6
Required amount of feedstock		lb/gallon	7.5	7.5	7.5
Average Price of Feedstock		$/lb	$ 0.52	$ 0.49	$ 0.43
Cost of Feedstock per Gallon		$/Gallon	$ 3.90	$ 3.66	$ 3.20
Carbon Content Inputs					
Carbon Reduction by Percent	Canola Oil	%	53%	53%	54%
	Distillers Corn Oil	%	96%	96%	96%
	Soybean Oil	%	78%	78%	78%
	Animal Fats	%	87%	87%	87%
	Yellow Grease	%	87%	87%	87%
	Renewable Diesel	%	79%	79%	80%
Diesel Carbon Intensity		gCO2e/MJ	94.43	95.21	96.00
Carbon Reduction in CO2e	Canola Oil	lb CO2e / gal	13.8	14.0	14.2
	Distillers Corn Oil	lb CO2e / gal	24.9	25.1	25.3
	Soybean Oil	lb CO2e / gal	20.2	20.4	20.6
	Animal Fats	lb CO2e / gal	22.5	22.7	23.0
	Yellow Grease	lb CO2e / gal	22.5	22.7	23.0
	Renewable Diesel	lb CO2e / gal	20.6	20.8	21.0
Average Carbon Reduction for Biodiesel		lb/gallon	20.2	20.8	21.3
Output					
Fixed Cost		$/Gallon	$0.26	$0.26	$0.26
Other Variable Costs		$/Gallon	$0.44	$0.43	$0.46
Value of Co-Products		$/Gallon	-$0.03	-$0.03	-$0.03
Cost of Production		**$/Gallon**	**$4.57**	**$4.32**	**$3.89**
Diesel Price		$/Gallon	$3.05	$3.11	$3.01
Biodiesel cost differential		$/Gallon	$1.52	$1.21	$0.88
Cost of Carbon		**$/Tonne**	**$166.14**	**$127.69**	**$90.92**

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Conversion Units	
454	grams/pound
118,296	Btu/gallon of diesel
0.001055	Btu/MJ
2,205	Pounds/metric ton

Feedstock Inputs

Sources: Feedstock breakdown values based on EIA data. The required amount of feedstock is derived from the EIA's breakdown of feedstock conversion

Carbon Content Inputs

Sources: Based on EPA estimates, supplemented by an USDA study and CARB.

Output

Sources: The estimated non-feedstock variable costs and fixed costs come from the Iowa State production cost model of a standard plant in Iowa producing biodiesel from soybean oil

Sources: The diesel prices are simple averages of spot price data from EIA: Los Angeles, CA Ultra-Low Sulfur CARB Diesel Spot Price (Dollars per Gallon)

Production of Biodiesel from Corn Oil Extraction at at Dry Mill Corn Ethanol Plants

Summary

ARB staff has developed a California corn oil biodiesel (BD) pathway in which the feedstock is produced in Midwestern corn ethanol plants and shipped to California for fuel production. The resulting pathway CI is 4.00 grams of CO_2-equivalent greenhouse gas emissions per mega joule of biodiesel produced (gCO_2e/MJ). Although the feedstock transport, biodiesel production, and finished fuel transport portions of this pathway are identical to those found in ARB's soybean-to-biodiesel pathway,[1] the feedstock production portion has no precedent in any other pathway. Calculation of the CI for that step requires that the energy consumption and greenhouse gas (GHG) generation associated with the production of corn oil be appropriately allocated between corn ethanol and corn oil.

In order to begin co-producing corn oil, standard dry mill corn ethanol plants need only be retrofitted with a centrifuge-based extraction system. This system extracts corn oil from the distillers' grains that emerge from the fermentation and distillation processes. As such, it has no direct impacts on the production of corn ethanol. It does, however, reduce the volume and lipid content of the distillers' grains with solubles (DGS) the plant produces.

The corn oil that is extracted from the DGS stream is an unrefined product that has two primary uses: a livestock feed additive and a biodiesel feedstock. This document summarizes a California Low Carbon Fuel Standard (LCFS) pathway in which corn oil produced at dry mill corn ethanol plants is used to produce biodiesel. This pathway does not apply to production processes in which the extracted corn oil is used for purposes other than the production of biodiesel for use as a transportation fuel. In addition, it is specific to ethanol production environments in which all DGS is fully dried. Dry DGS has a moisture content of around ten percent.

ARB staff's estimate of the carbon intensity (CI) of corn oil biodiesel is based on information made available by Greenshift Inc.—a company that has commercialized a corn oil extraction process. Although Greenshift's is not the only available extraction process, more information is publicly available on its process than is available on alternative systems.

Under the Greenshift process, corn oil is removed from the DGS process stream through a combination of washing and centrifuging. The extracted corn oil is shipped to a biodiesel production plant where it is converted to fatty acid methyl

[1] ARB (2009). Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME); version 3.0: http://www.arb.ca.gov/fuels/lcfs/121409lcfs_soybean.pdf

ester (FAME) biodiesel using a transesterification process—the same process that is used to produce biodiesel from soy oil and other oil- and fat-based feedstocks.

The equipment used to extract corn oil at corn ethanol plants consumes both thermal and electrical energy. This additional energy consumptions is more than offset, however, by energy savings realized during the DGS drying process. Energy is saved because the removal of corn oil both reduces the mass of the DGS entering the dryers, and improves the efficiency with which that DGS transfers heat. Based on information from Greenshift, ARB staff estimates that the production of corn oil at an ethanol plant reduces the net energy consumption of that plant by about nine percent. These savings would be realized only when all DGS is fully dried.

At dry mill plants that produce both ethanol and corn oil, the primary product is ethanol. Staff has no reason to believe that corn oil will ever replace ethanol as the primary product at such plants. Since corn oil production is incremental and secondary to ethanol production, staff has concluded that no portion of the GHG gas emissions associated with the production of ethanol should be allocated to corn oil biodiesel. Because corn oil extraction equipment can be installed in existing corn ethanol plants, ARB staff believes that the carbon intensity of corn oil should be calculated as a marginal, or incremental, carbon intensity, consisting only the additional energy requirements and savings that occur as a result of operating corn oil extraction equipment.

Staff is confident that corn oil biodiesel produced according to the pathway summarized above would have a carbon intensity of 4.00 gCO_2e/MJ. For that reason, staff recommends that the Executive Officer approve that pathway.

Independent Statistics & Analysis
U.S. Energy Information Administration

Monthly Biodiesel Production Report

December 2013

With Data for October 2013

This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the United States Government. The views in this report therefore should not be construed as representing those of the Department of Energy or other Federal agencies.

Biodiesel Highlights and Background, Data for October 2013

Highlights

Production – U.S. production of biodiesel was 132 million gallons in October 2013. Biodiesel production during October 2013 was about 5 million gallons higher than production in September 2013. Biodiesel production from the Midwest region (Petroleum Administration for Defense District 2) was 67% of the U.S. total. Production came from 112 biodiesel plants with capacity of 2.2 billion gallons per year.

Sales – Producer sales of biodiesel during October 2013 included 92 million gallons sold as B100 (100% biodiesel) and an additional 41 million gallons of B100 sold in biodiesel blends with diesel fuel derived from petroleum.

Feedstocks – There were a total of 1,009 million pounds of feedstocks used to produce biodiesel in October 2013. Soybean oil remained the largest biodiesel feedstock during October 2013 with 551 million pounds consumed.

Background

The Monthly Biodiesel Production Report provides data on operations of the U.S. biodiesel industry as part of EIA's response to section 1508 of the Energy Policy Act of 2005 which directed EIA to publish information on renewable fuels including biodiesel. Data are provided for the U.S. and in selected cases by state and region.

The source of data is Form EIA-22M Monthly Biodiesel Production Survey, used to collect the following information from registered producers of biodiesel.

- plant location, operating status, and annual production capacity
- production of 100% biodiesel (B100)
- biodiesel coproduct production
- stocks
- feedstock, alcohol input, and catalysts used in biodiesel production
- sales of B100 and blended biodiesel from producing plants
- sales of biodiesel to end-users

Form EIA-22M provides data necessary to monitor growth of the biodiesel industry in order to allow Congress to assess whether objectives of Section 503 of the Energy Policy Act of 1992 and Section 1508 of the Energy Policy Act of 2005 are being achieved.

Table 1. U.S. Biodiesel Production Capacity and Production
(million gallons)

Period	Annual Production Capacity	Monthly B100 Production
2011		
January	2,114	35
February	2,104	40
March	2,081	60
April	2,101	71
May	2,064	77
June	2,069	81
July	1,958	92
August	2,008	95
September	2,087	96
October	2,119	105
November	2,098	105
December	2,090	109
Total	--	**967**
2012		
January	2,203	74
February	2,203	79
March	2,188	95
April	2,158	94
May	2,151	102
June	2,138	93
July	2,134	89
August	2,135	91
September	2,165	82
October	2,162	75
November	2,091	57
December	2,054	59
Total	--	**991**
2013		
January	2,086	66
February	2,090	68
March	2,160	98
April	2,162	106
May	2,165	111
June	2,148	113
July	2,144	128
August	2,141	128
September	2,153	127
October	2,190	132
10 Month Total	--	**1,076**
2012 10 Month Total	--	**874**
2011 10 Month Total	--	**753**

-- = Not Applicable

R = Revised

Totals may not equal the sum of components due to independent rounding.
B100 is the industry designation for pure biodiesel; a biodiesel blend contains both pure biodiesel and petroleum diesel fuel.

Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Table 2. U.S. Biodiesel Production, Sales, and Stocks
(million gallons)

Period	B100 Production	Sales of B100	Sales of B100 Included in Biodiesel Blends	Ending Stocks of B100	B100 Stock Change
2011					
January	35	22	9	17	4
February	40	27	13	17	1
March	60	41	17	19	2
April	71	47	22	21	2
May	77	50	27	23	2
June	81	62	24	19	(4)
July	92	66	22	23	4
August	95	64	30	25	2
September	96	68	37	21	(4)
October	105	69	36	25	4
November	105	66	39	26	1
December	109	59	62	14	(12)
Total	**967**	**641**	**339**	--	**1**
2012					
January	74	45	16	26	12
February	79	57	15	33	7
March	95	75	17	36	2
April	94	68	24	40	5
May	102	77	33	37	(3)
June	93	80	19	31	(6)
July	89	72	18	29	(1)
August	91	73	18	30	1
September	82	62	17	32	2
October	75	62	12	33	1
November	57	53	12	26	(8)
December	59	44	10	31	5
Total	**991**	**767**	**212**	--	**16**
2013					
January	66	52	15	31	(1)
February	68	44	23	33	2
March	98	68	29	35	2
April	106	79	31	34	(1)
May	111	77	40	28	(6)
June	113	77	36	28	1
July	128	87	40	30	2
August	128	91	40	28	(2)
September	127	92	37	27	(1)
October	132	92	41	26	(1)
10 Month Total	**1,076**	**758**	**331**	--	**(7)**
2012 10 Month Total	**874**	**670**	**189**	--	**19**
2011 10 Month Total	**753**	**516**	**238**	--	**13**

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Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Table 3. U.S. Inputs to Biodiesel Production
(million pounds)

Period	Feedstock Inputs							
	Vegetable Oils						Animal Fats	
	Canola Oil	Corn Oil	Cottonseed Oil	Palm Oil	Soybean Oil	Other	Poultry	Tallow
2011								
January	8	17	-	W	150	W	14	11
February	26	13	-	W	150	W	14	11
March	68	14	-	W	190	W	19	27
April	88	20	-	W	236	W	15	47
May	113	21	-	W	264	W	16	36
June	75	34	-	W	311	W	23	49
July	77	35	-	W	367	W	26	64
August	84	37	W	W	398	W	34	38
September	84	27	W	W	430	W	20	49
October	69	30	W	W	527	W	31	39
November	84	27	W	W	538	W	13	31
December	71	30	W	W	592	W	15	27
Total	**847**	**304**	**W**	**W**	**4,153**	**W**	**240**	**431**
2012								
January	73	50	-	W	306	W	20	26
February	90	51	-	W	321	W	8	20
March	117	54	-	W	388	W	11	24
April	112	54	-	W	350	W	13	45
May	85	56	-	W	429	W	16	50
June	103	55	-	W	369	W	14	28
July	66	54	-	W	347	W	20	30
August	48	59	-	W	385	W	21	44
September	46	55	-	W	322	W	19	49
October	16	59	-	W	307	W	14	44
November	18	48	-	W	246	W	11	22
December	16	50	-	W	273	W	9	3
12 Month Total	**790**	**646**	**-**	**W**	**4,042**	**W**	**176**	**385**
2013								
January	16	60	-	W	300	W	7	15
February	38	61	-	W	275	W	8	28
March	39	71	-	W	424	W	9	53
April	47	71	-	W	423	W	15	56
May	W	91	-	W	416	W	20	61
June	W	98	-	W	461	W	19	54
July	W	108	-	93	480	2	17	45
August	79	106	-	W	510	2	17	48
September	W	95	-	93	502	2	14	50
October	82	85	-	100	551	W	13	23
10 Month Total	**488**	**846**	**-**	**476**	**4,342**	**31**	**139**	**433**
2012 10 Month Total	**756**	**547**	**-**	**W**	**3,524**	**W**	**156**	**360**
2011 10 Month Total	**692**	**248**	**-**	**W**	**3,023**	**W**	**212**	**371**

- = No data reported.

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Totals may not equal the sum of components due to independent rounding.

Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Table 3a. Inputs to Biodiesel Production (continuation of table 3)
(million pounds)

Period	Feedstock Inputs						Other Inputs	
	Animal Fats		Recycled Feeds		Algae	Other	Alcohol	Catalysts
	White Grease	Other	Yellow Grease	Other				
2011								
January	31	3	18	10	-	7	20	4
February	48	2	19	11	-	4	20	3
March	60	12	33	10	-	7	34	5
April	55	8	52	11	-	(s)	46	7
May	57	10	41	15	-	(s)	48	8
June	55	7	50	18	-	1	58	9
July	49	6	45	20	-	2	62	9
August	48	15	47	19	-	5	63	9
September	40	4	50	21	-	(s)	64	9
October	29	7	42	21	-	(s)	71	10
November	35	8	39	20	-	(s)	71	10
December	26	5	35	20	-	(s)	68	11
12 Month Total	**533**	**85**	**471**	**195**	**-**	**27**	**626**	**94**
2012								
January	29	3	37	18	-	(s)	45	8
February	29	4	41	22	-	-	47	8
March	31	6	61	21	-	(s)	53	9
April	41	5	67	24	-	-	56	10
May	38	5	61	27	-	-	62	10
June	39	4	64	27	-	-	57	10
July	31	4	65	25	-	(s)	57	9
August	34	4	70	28	-	(s)	55	10
September	33	4	65	25	-	-	50	9
October	41	4	60	29	-	(s)	48	9
November	28	4	36	23	-	-	39	7
December	35	2	45	21	-	(s)	38	6
12 Month Total	**408**	**48**	**670**	**289**	**-**	**1**	**607**	**105**
2013								
January	31	3	46	23	-	1	50	7
February	32	3	51	23	-	(s)	47	7
March	36	2	72	15	-	(s)	63	10
April	48	2	79	19	-	3	70	11
May	41	W	88	20	-	W	78	12
June	41	4	93	26	-	W	77	12
July	43	2	97	31	-	W	90	13
August	41	W	92	31	-	W	89	13
September	38	W	107	22	-	W	89	13
October	36	1	81	27	-	W	81	13
10 Month Total	**387**	**23**	**806**	**237**	**-**	**38**	**734**	**111**
2012 10 Month Total	**346**	**43**	**591**	**246**	**-**	**1**	**530**	**92**
2011 10 Month Total	**472**	**74**	**397**	**156**	**-**	**27**	**486**	**73**

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Totals may not equal the sum of components due to independent rounding.

Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Table 4. Biodiesel Producers and Production Capacity by State, October 2013

State	Number of Producers	Annual Production Capacity (million gallons per year)
Alabama	3	47
Alaska	-	-
Arizona	1	2
Arkansas	3	85
California	9	61
Colorado	-	-
Connecticut	3	13
Delaware	-	-
District of Columbia	-	-
Florida	-	-
Georgia	3	16
Hawaii	1	5
Idaho	1	1
Illinois	5	167
Indiana	2	104
Iowa	9	280
Kansas	1	1
Kentucky	5	68
Louisiana	1	12
Maine	1	1
Maryland	-	-
Massachussetts	1	1
Michigan	2	18
Minnesota	4	107
Mississippi	3	105
Missouri	8	188
Montana	-	-
Nebraska	-	-
Nevada	1	1
New Hampshire	1	4
New Jersey	-	-
New Mexico	-	-
New York	1	0
North Carolina	4	10
North Dakota	1	85
Ohio	3	67
Oklahoma	1	15
Oregon	2	18
Pennsylvania	4	87
Rhode Island	1	1
South Carolina	2	40
South Dakota	-	-
Tennessee	2	2
Texas	13	428
Utah	1	10
Vermont	-	-
Virginia	3	9
Washington	3	104
West Virginia	-	-
Wisconsin	3	29
Wyoming	-	-
U.S. Total	**112**	**2,190**

- = No data reported.

Totals may not equal the sum of components due to independent rounding.

Number of producers is a count of plants with operable capacity during the report month.

Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Table 5. Biodiesel (B100) Production by Petroleum Administration for Defense District (PADD)
(million gallons)

Period	East Coast (PADD 1)	Midwest (PADD 2)	Gulf Coast (PADD 3)	Rocky Mountain (PADD 4)	West Coast (PADD 5)	U.S.
2011						
January	3	30	1	-	1	35
February	3	32	4	-	1	40
March	3	47	6	-	2	60
April	3	54	10	-	3	71
May	4	58	11	-	4	77
June	4	56	14	-	7	81
July	5	65	17	-	5	92
August	5	66	20	-	5	95
September	6	65	20	-	6	96
October	7	73	22	-	4	105
November	6	71	23	-	4	105
December	6	77	23	-	4	109
Total	**56**	**695**	**171**	**-**	**46**	**967**
2012						
January	5	50	15	(s)	3	74
February	4	54	18	(s)	3	79
March	6	67	18	(s)	4	95
April	6	63	21	1	3	94
May	7	71	20	1	4	102
June	6	67	17	(s)	3	93
July	5	66	15	(s)	3	89
August	6	66	16	(s)	2	91
September	6	60	14	(s)	3	82
October	5	54	14	(s)	2	75
November	2	44	8	(s)	2	57
December	5	48	4	1	1	59
Total	**62**	**711**	**180**	**4**	**35**	**991**
2013						
January	4	52	9	(s)	1	66
February	4	50	12	(s)	1	68
March	5	66	22	(s)	6	98
April	6	70	23	(s)	7	106
May	5	75	21	(s)	10	111
June	6	79	22	(s)	5	113
July	6	82	30	(s)	8	128
August	6	86	29	(s)	6	128
September	6	81	30	(s)	9	127
October	7	88	27	1	10	132
10 Month Total	**55**	**729**	**225**	**2**	**63**	**1,076**
2012 10 Month Total	**56**	**618**	**168**	**3**	**30**	**874**
2011 10 Month Total	**43**	**546**	**125**	**-**	**38**	**753**

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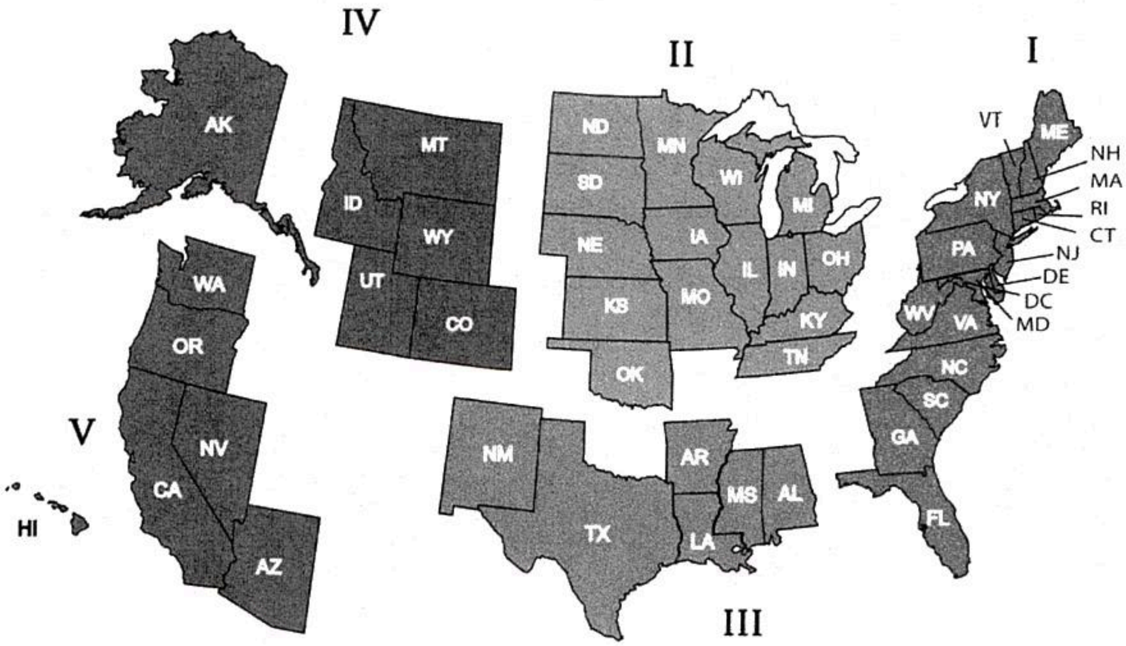
B100 is the industry designation for pure biodiesel; a biodiesel blend contains both pure biodiesel and petroleum diesel fuel.

See Appendix A for a map of states included in each PADD.

Source: U.S. Energy Information Administration, Form EIA-22M "Monthly Biodiesel Production Survey"

Appendix A Petroleum Administration for Defense Districts (PADD)



NOTE: MAP NOT TO SCALE

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To: Argyropoulos, Paul[Argyropoulos.Paul@epa.gov]
From: Larry Schafer
Sent: Tue 2/18/2014 5:37:53 PM
Subject: FW: final version of presentation
2014.1.16 Draft Presentation on RFS Carbon Reduction - Final for Filing.pptx

For today's discussion …

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From: David DeRamus [mailto:david.deramus@bateswhite.com]
Sent: Monday, January 27, 2014 9:34 AM
To: Larry Schafer
Cc: Anne Steckel; J. Alan Weber; Collin Cain
Subject: final version of presentation

Here's a final version of the PPT with the draft language taken off; the low 2014 forecast eliminated; a few conforming word changes; and some minor format changes.

Thx

David

David DeRamus, Ph.D.

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********************** ATTACHMENT NOT DELIVERED **********************

Biodiesel Renewable Fuel Standard

Analysis of Cost of Carbon Reduction

DRAFT – PRELIMINARY ANALYSIS

January 27, 2014

ED.000312.0365.0000 2655

Summary of conclusions

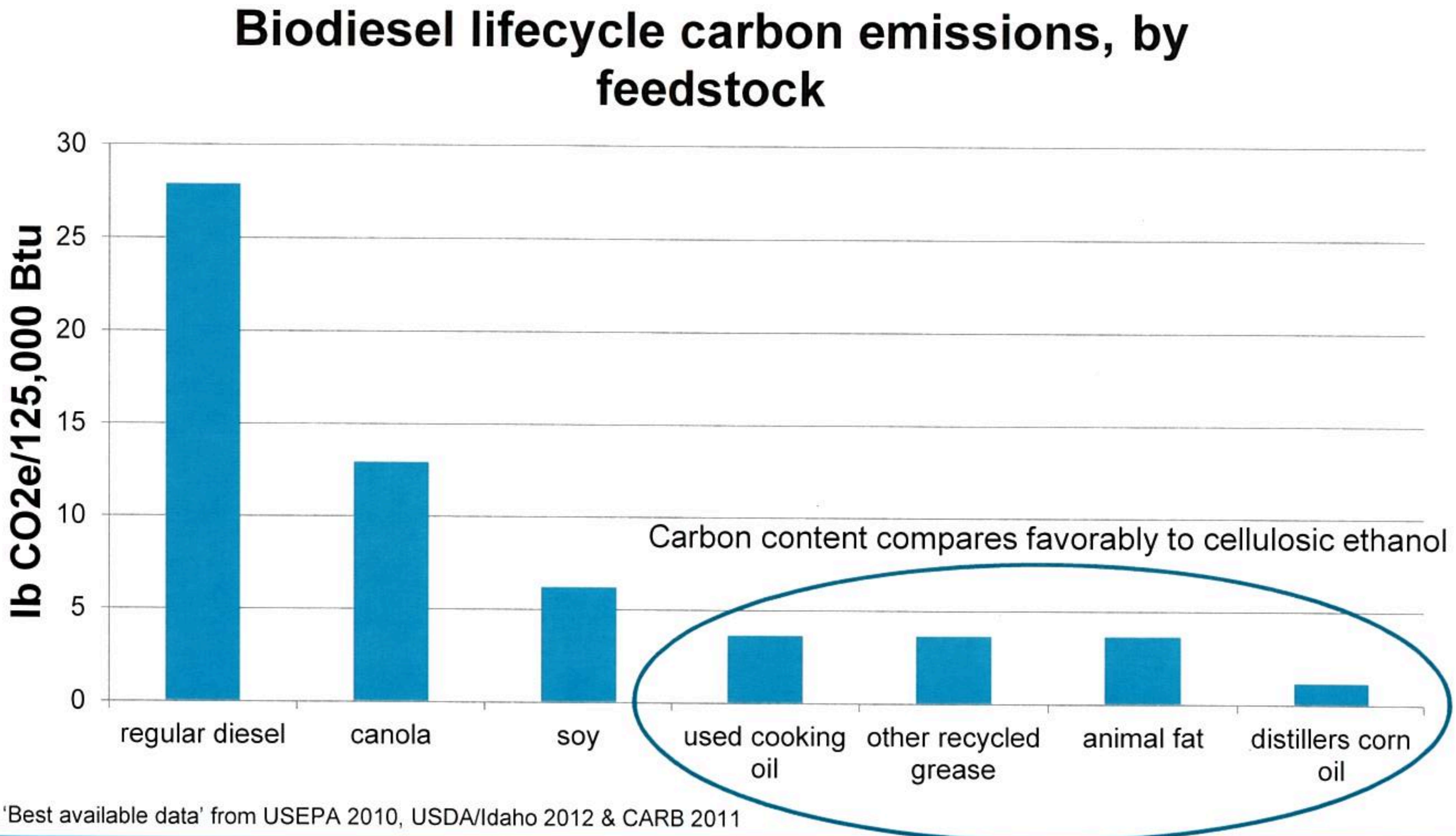
- Biodiesel reduces CO_2 emissions by 81% relative to diesel
  - Based on current mix of biodiesel feedstocks
  - Biodiesel carbon footprint steadily improving as mix of feedstocks changes
  - Biodiesel reduced 2013 CO_2 emissions by 16.4 million metric tons
- Biodiesel production costs have declined, especially relative to petroleum diesel
  - Lower feedstock costs relative to petroleum diesel
  - Greater availability of feedstocks with lower carbon footprint
  - Technology changes allow greater use of lower-cost, lower-carbon feedstocks
- Cost of carbon reduction via biodiesel is currently \$71 – \$91 per metric ton of CO_2, before accounting for other benefits
- Biodiesel capacity and feedstocks are available to support further production increases with minimal cost/price impacts

2653

Estimates of Biodiesel Cost of Carbon Reduction

2655

Biodiesel has a significantly lower carbon footprint than petroleum



Source: 'Best available data' from USEPA 2010, USDA/Idaho 2012 & CARB 2011

On average, biodiesel emits 81% less CO_2 than petroleum diesel with current feedstocks

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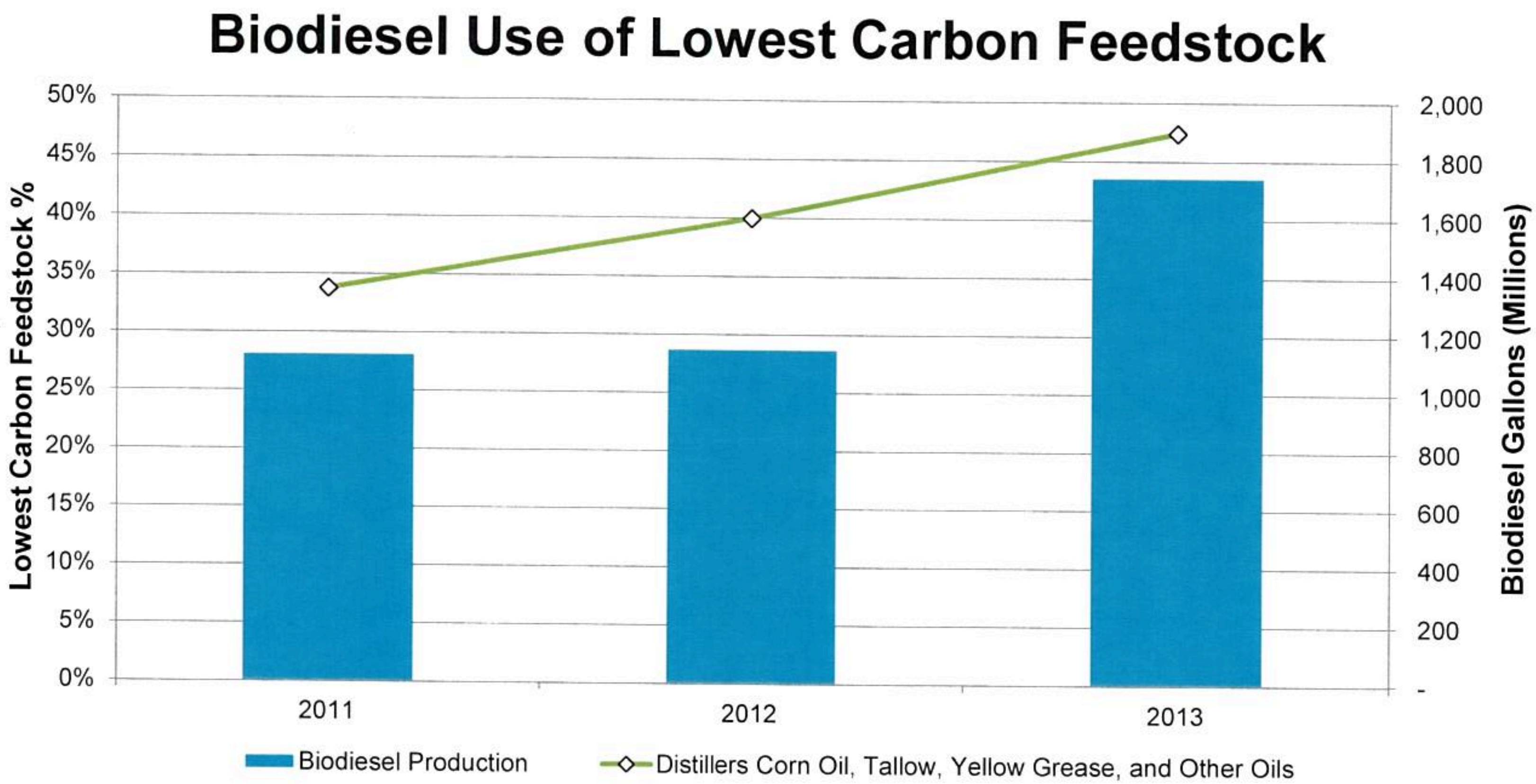
Currently, 103 gallons of biodiesel = 1 ton reduction in CO2 emissions

- With current feedstocks, biodiesel emits 81% less CO2 than petroleum diesel (normalized for energy content)
- 2013 wtd. average CO2 reduction: 21.3 pounds/gallon biodiesel
- 2204 lbs / 21.3 lbs/gallon = 103 gallons biodiesel to reduce CO2 emissions by 1 metric ton
- Current annual CO2 reductions due to biodiesel: 16.4 million metric tons
  - 1,700 million gallons x 21.3 lbs / 2204 = 16.43 million metric tons CO2e
  - Equivalent to the emissions from 3.4 million cars*

*Source: EIA's emissions calculator

2653

Share of biodiesel production from lower carbon footprint feedstocks has increased, even with rising biofuel production

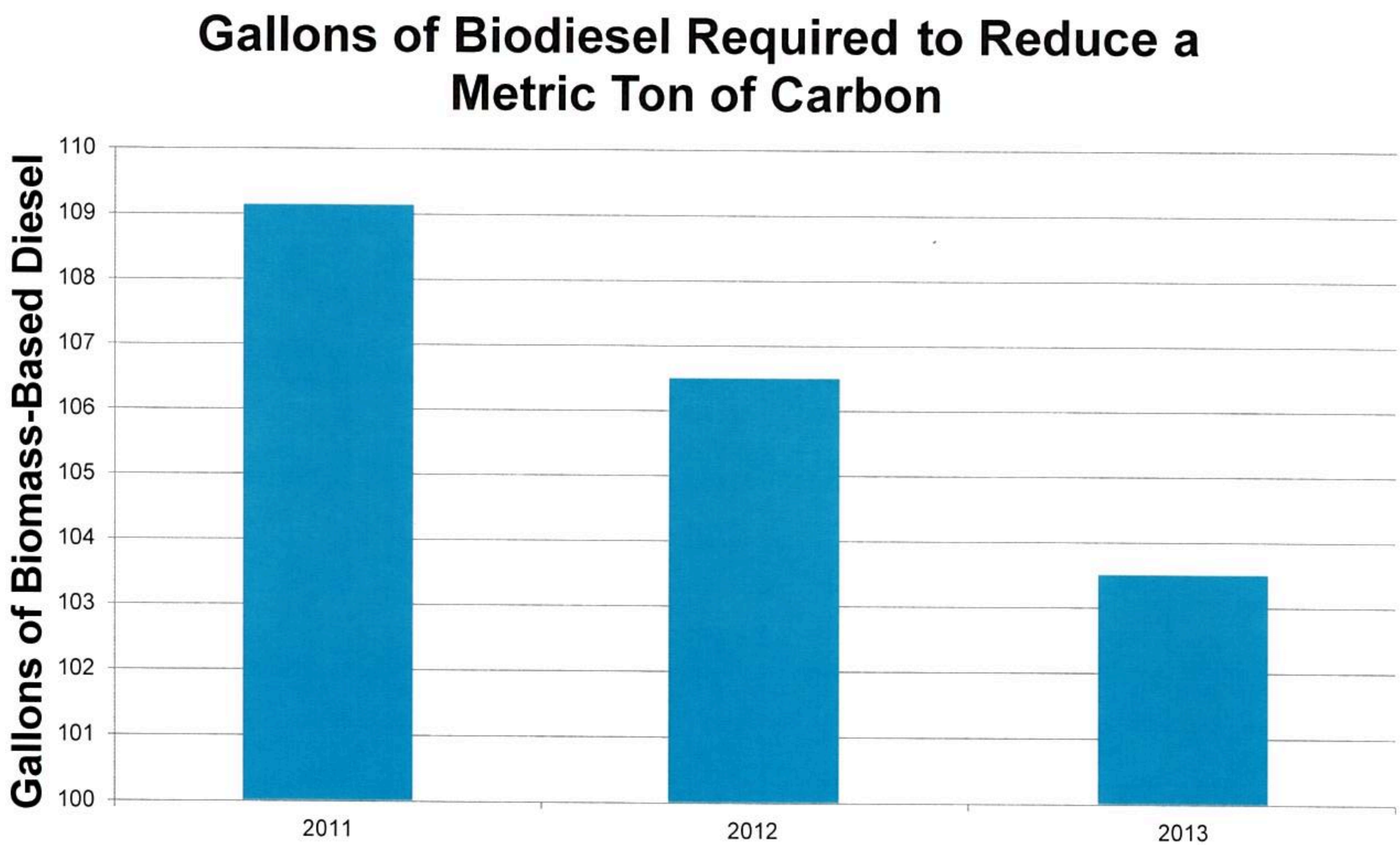


Source: EIA Monthly Biodiesel Production Report (November 2013).

At the margin, increased biodiesel production has used distillers corn oil or waste grease as feedstocks

2655

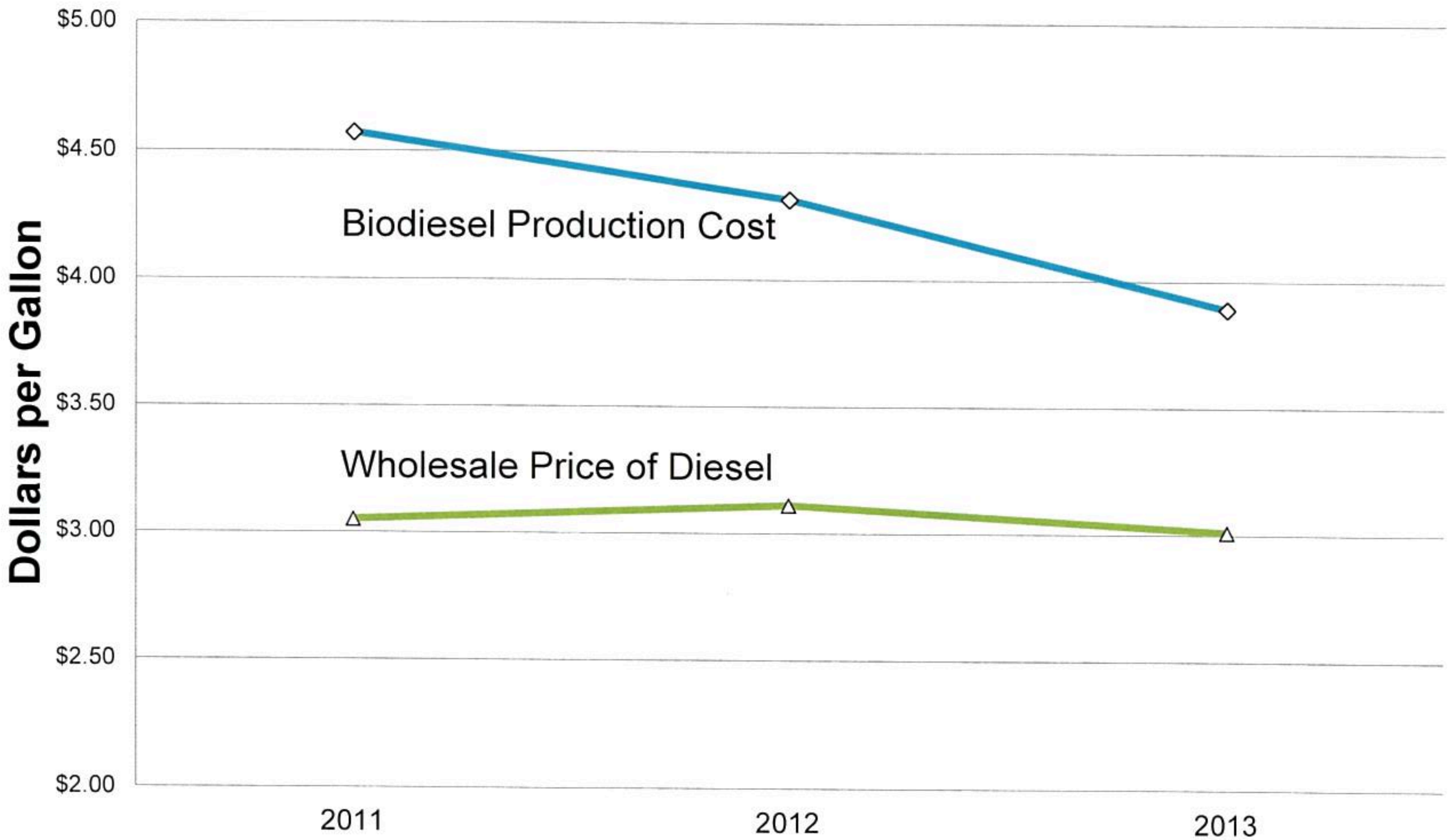
Changing feedstocks have made biodiesel increasingly effective at reducing carbon emissions



Source: EIA Monthly Biodiesel Production Report , USEPA , USDA and CARB carbon reduction figures

2685

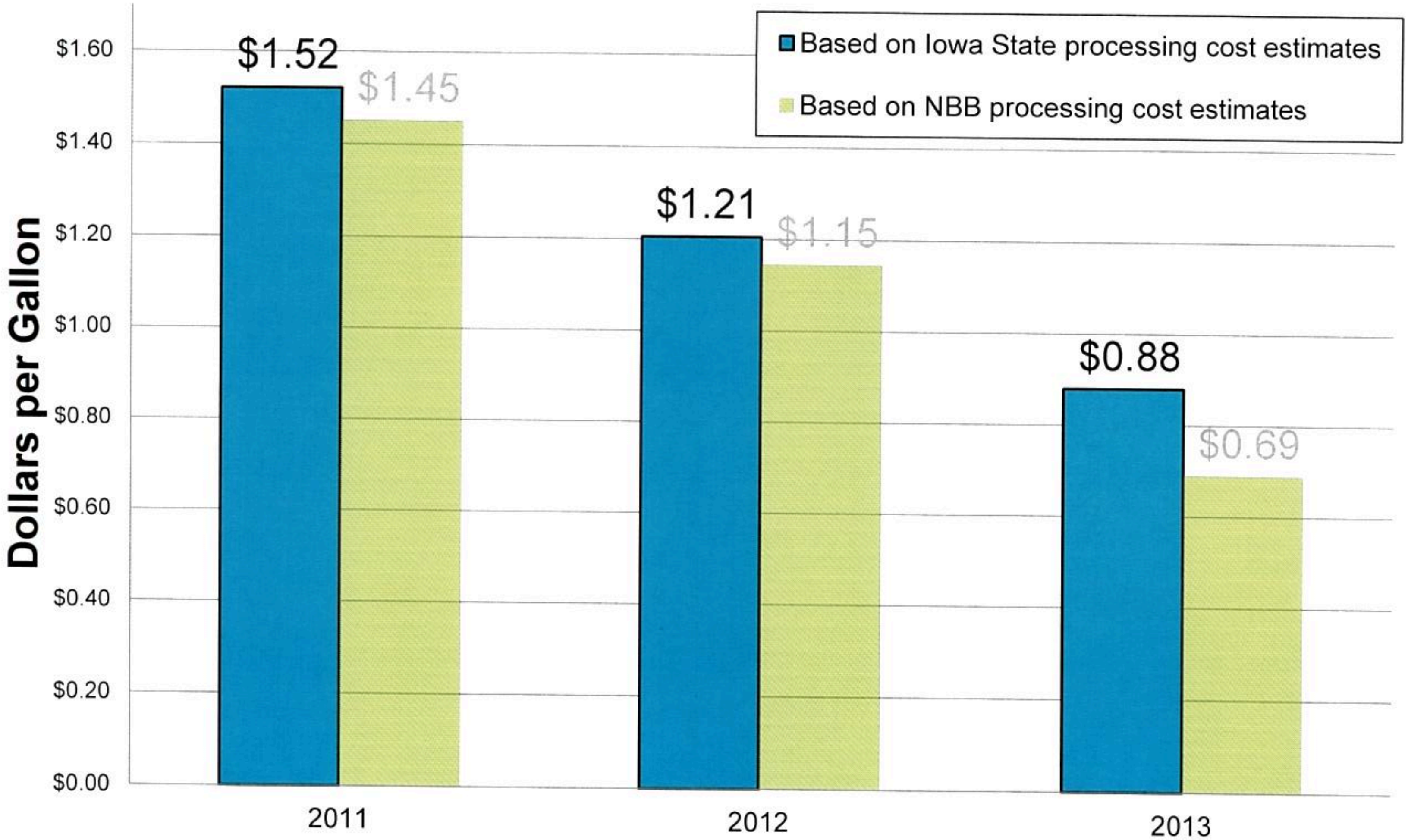
Biodiesel production costs have been declining, especially relative to the price of petroleum diesel



Sources: Production cost estimates based on output and feedstock data from EIA for biodiesel and industry estimates for renewable diesel; feedstock prices from Jacobsen; processing costs from Iowa State biodiesel plant model.

2653

The difference between the cost of biodiesel and the wholesale price of diesel has dropped by over 40% since 2011



2685

Biodiesel production costs are falling with increased reliance on lower cost feedstocks

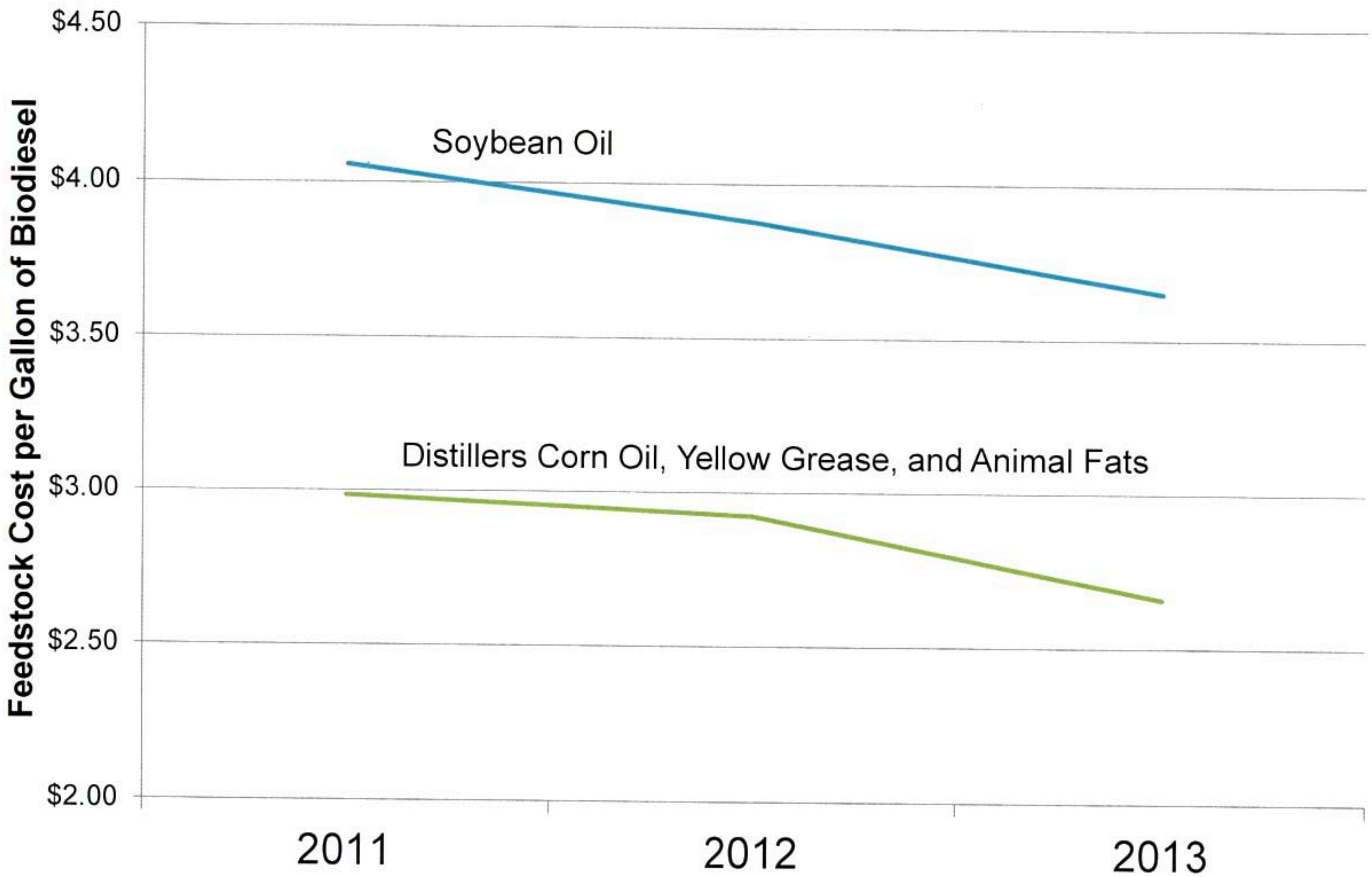
	2011	2012	2013
Weighted average feedstock cost	$3.90	$3.66	$3.20
Average processing cost	$0.67	$0.66	$0.69
Total production cost	**$4.57**	**$4.32**	**$3.89**
Average wholesale diesel price	$3.05	$3.11	$3.01
Biodiesel production cost difference	**$1.52**	**$1.21**	**$0.88**

Sources: Production cost estimates based on output and feedstock data from EIA for biodiesel and industry estimates for renewable diesel; feedstock prices from Jacobsen; processing costs from Iowa State biodiesel plant model.

Processing costs from Iowa State model are likely overstated, especially with higher plant utilization in 2013

265

Lower biodiesel production costs reflect overall feedstock price decline and cost advantage of lower carbon footprint feedstocks



Source: Feedstock prices from Jacobsen; feedstock prices per pound were multiplied by 7.5 to determine the cost per gallon of biodiesel.

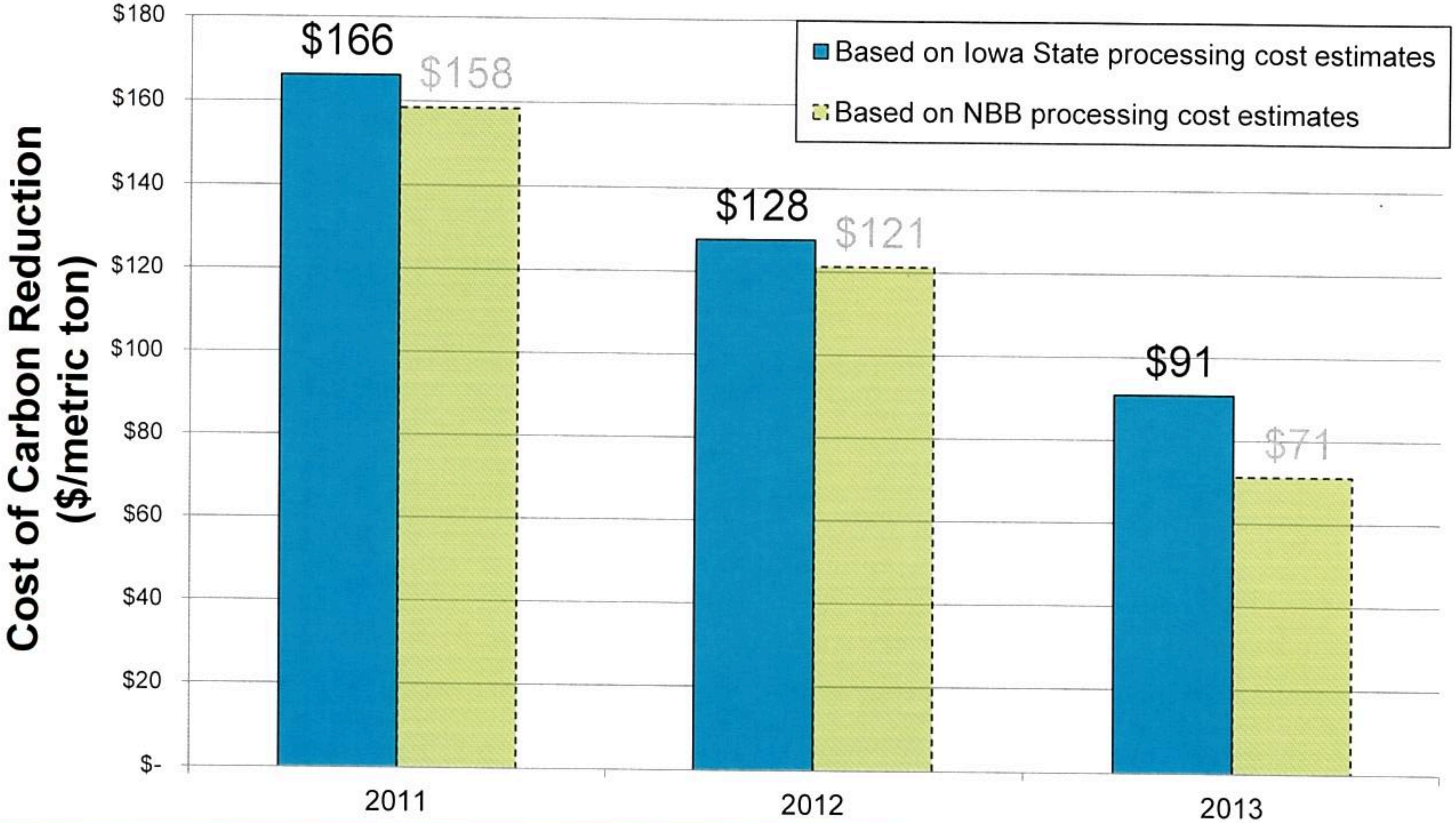
Expanded use of lower-cost/lower-carbon footprint feedstocks due to recent investments in new technology

- New technology increased production of lower carbon feedstocks
  - Distillers corn oil
  - Waste oils
- Updates to existing biofuel production systems
  - Flexible plants able to use different feedstock
- Alternative processing systems/pathways, e.g.:
  - Hydrotreating
    - Removes sulfur, oxygen, and nitrogen
    - Produces propane as a byproduct
  - Biomass-to-Liquid
    - Biomass is gasified
    - Resulting gas is converted into oil

Investments in technology for new feedstocks and more efficient biodiesel production due to increased biodiesel demand

2653

Based on 2013 feedstocks and production costs, biodiesel's cost of carbon reduction is approximately \$71 - \$91 per metric ton of CO2



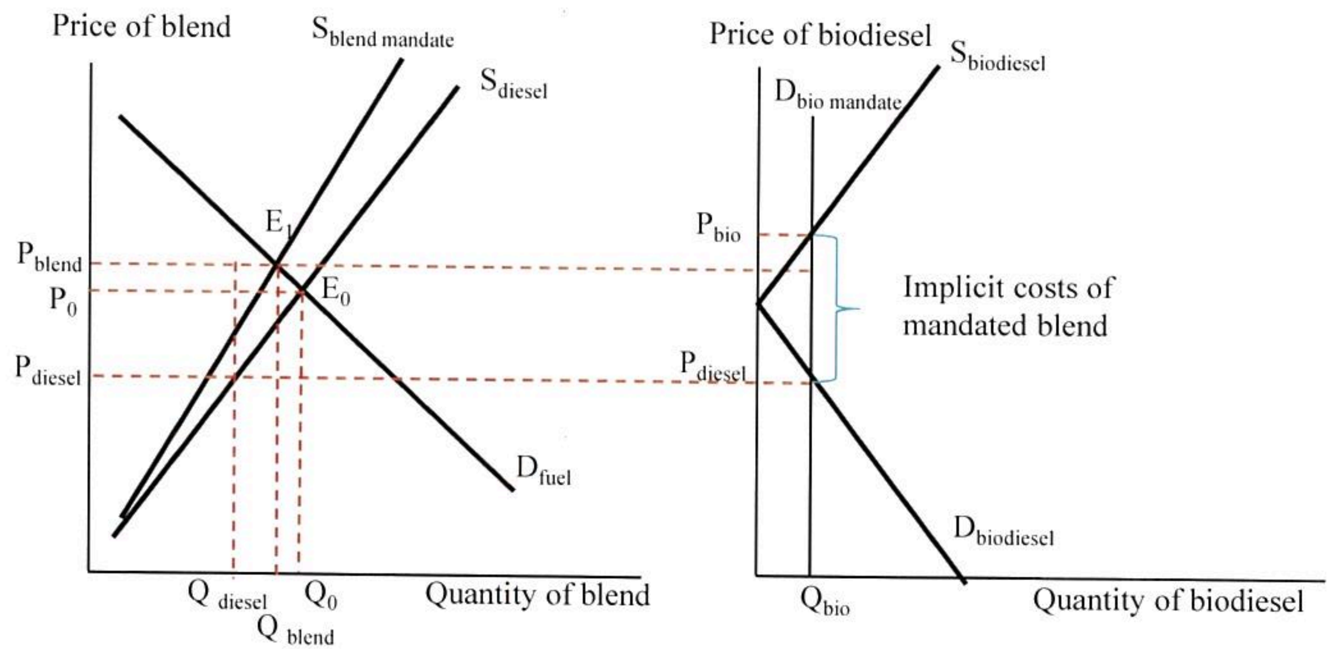
Changes in production costs and feedstocks have lowered biodiesel's cost of carbon reduction by 45% since 2011

Calculation details: CO_2 reduction cost from biodiesel production cost differential relative to wholesale diesel price

- $0.88 biodiesel cost differential relative to wholesale diesel
  - Wholesale diesel price in 2013 averaged $3.01/gal
  - Production cost of biodiesel in 2013 was $3.89/gal
- 21.3 lbs CO_2 emission reduction from biodiesel displacing one gallon of petroleum diesel (0.00967MT/gal)
  - Based on carbon intensity estimates by feedstock and current feedstock production shares
- $0.88/gal ÷ 0.00967MT/gal = $91/MT CO_2 reduction

2653

An upper bound estimate of the cost of RFS2 is the cost differential between biodiesel and petroleum diesel



Blend Market with Volume Mandate **Biodiesel Market with Volume Mandate**

Adapted from Taheripour and Tyner, "Welfare Assessment of the Renewable Fuel Standard: Economic Efficiency, Rebound Effect, and Policy Interaction in a General Equilibrium Framework," Purdue University Working Paper, June 2012, presented at 15th Annual Conference on Global Economic Analysis.

5502

Cost of carbon reduction from biodiesel should be calculated net of other benefits

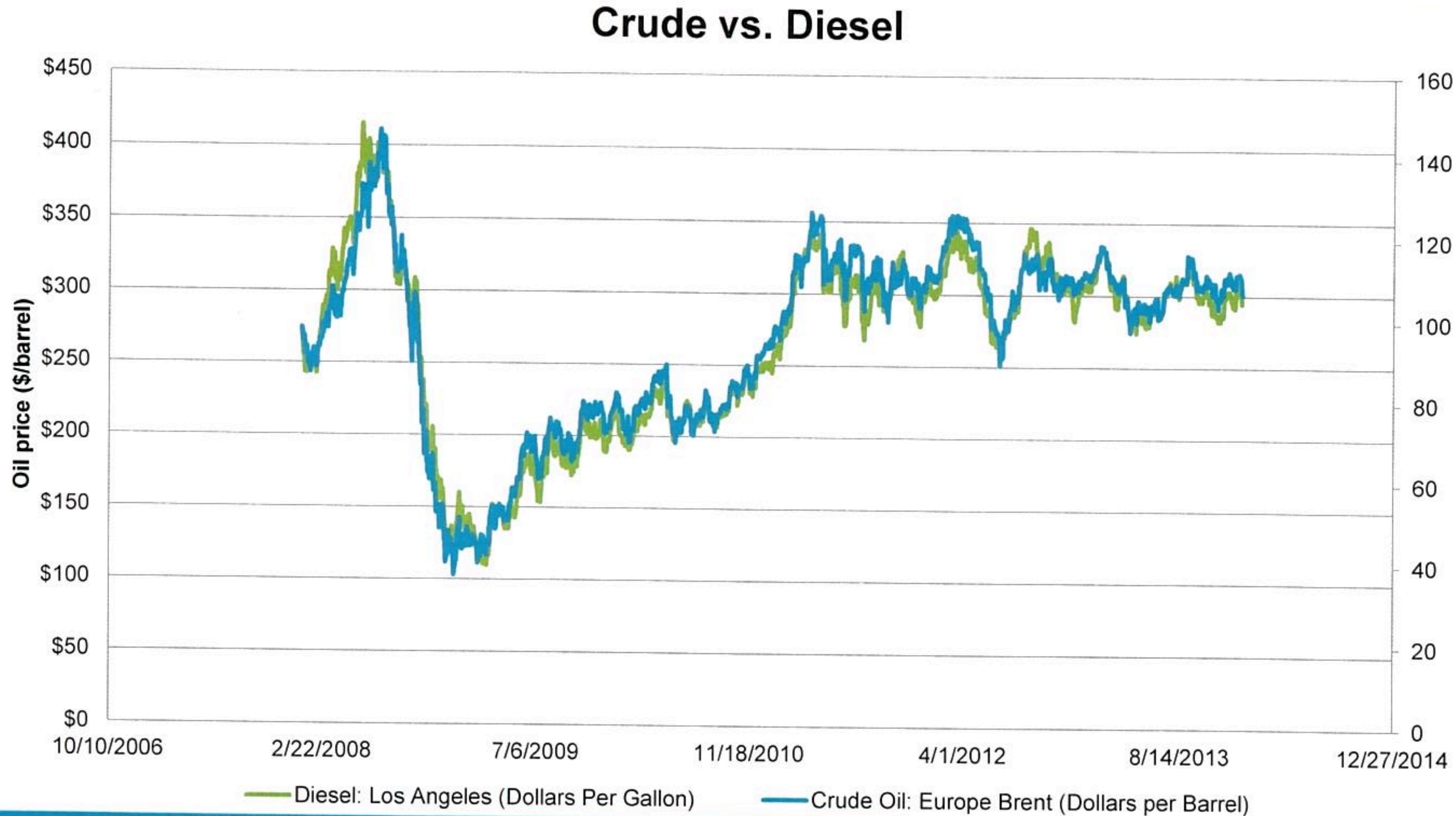
- RFS2 has three distinct policy objectives:
  - Agricultural policy: increase rural employment, farm incomes
  - "Energy independence:" reduce petroleum imports
  - Reduce GHG emissions
- Biodiesel is effective at reducing CO2 and other emissions, e.g. particulate matter ($PM_{2.5}$)
  - Biodiesel reduces $PM_{2.5}$ emissions by 47%[1]
  - EPA estimate of benefits from $PM_{2.5}$ reduction: $230k – 880k/ton[2]
- RFS2's other objectives also have significant monetary benefits

[1] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions," October 2002, p. 37.
[2] EPA, "Report to Congress on Black Carbon," March 2012, p. 143.

Our initial estimate of biodiesel's cost of carbon reduction does not account for these other benefits

2655

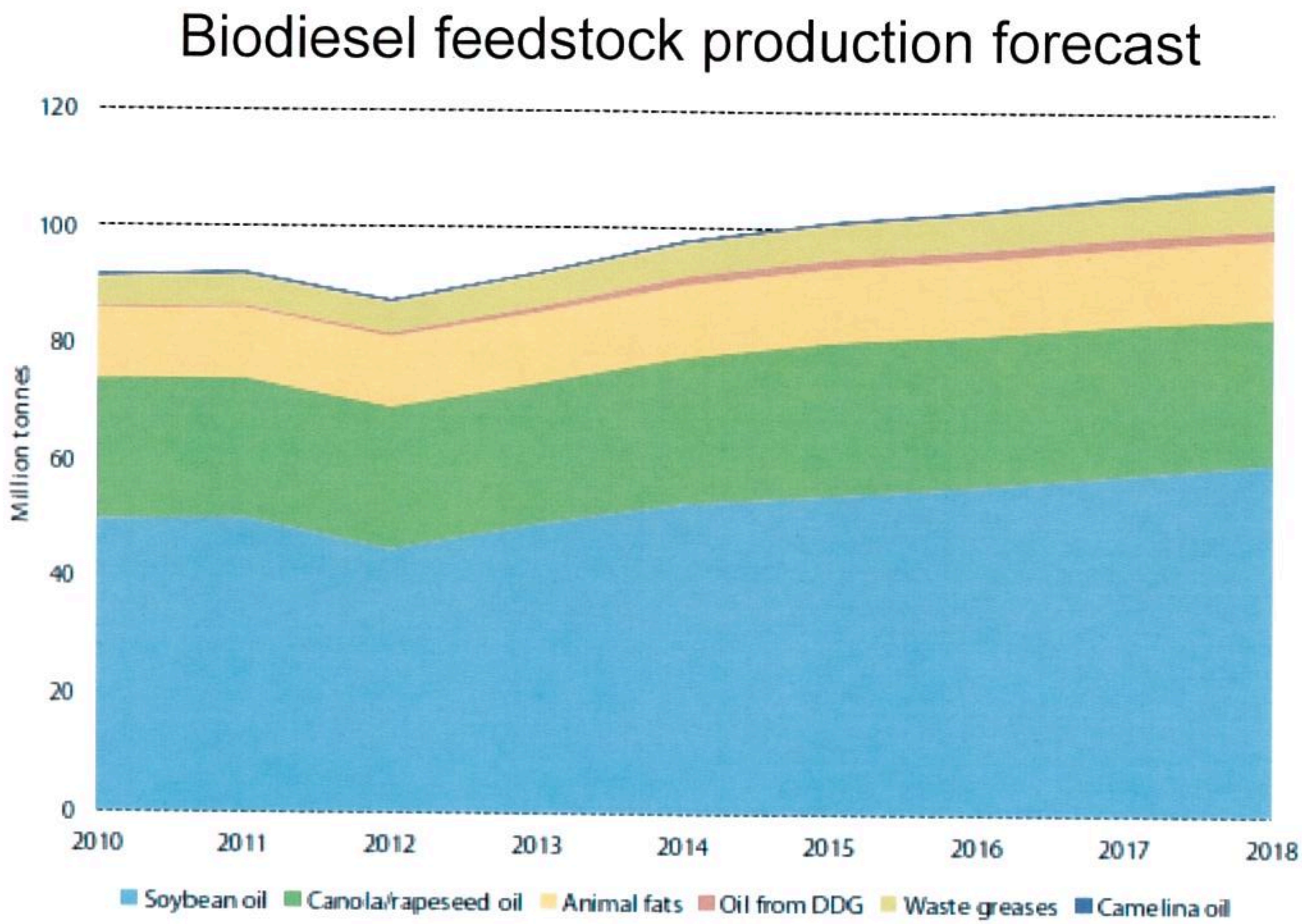
No indication that D4 RIN prices have had a significant impact on retail price of diesel fuel



Whether RIN costs are passed through to consumers is important in analyzing welfare effects of RFS2

SSR

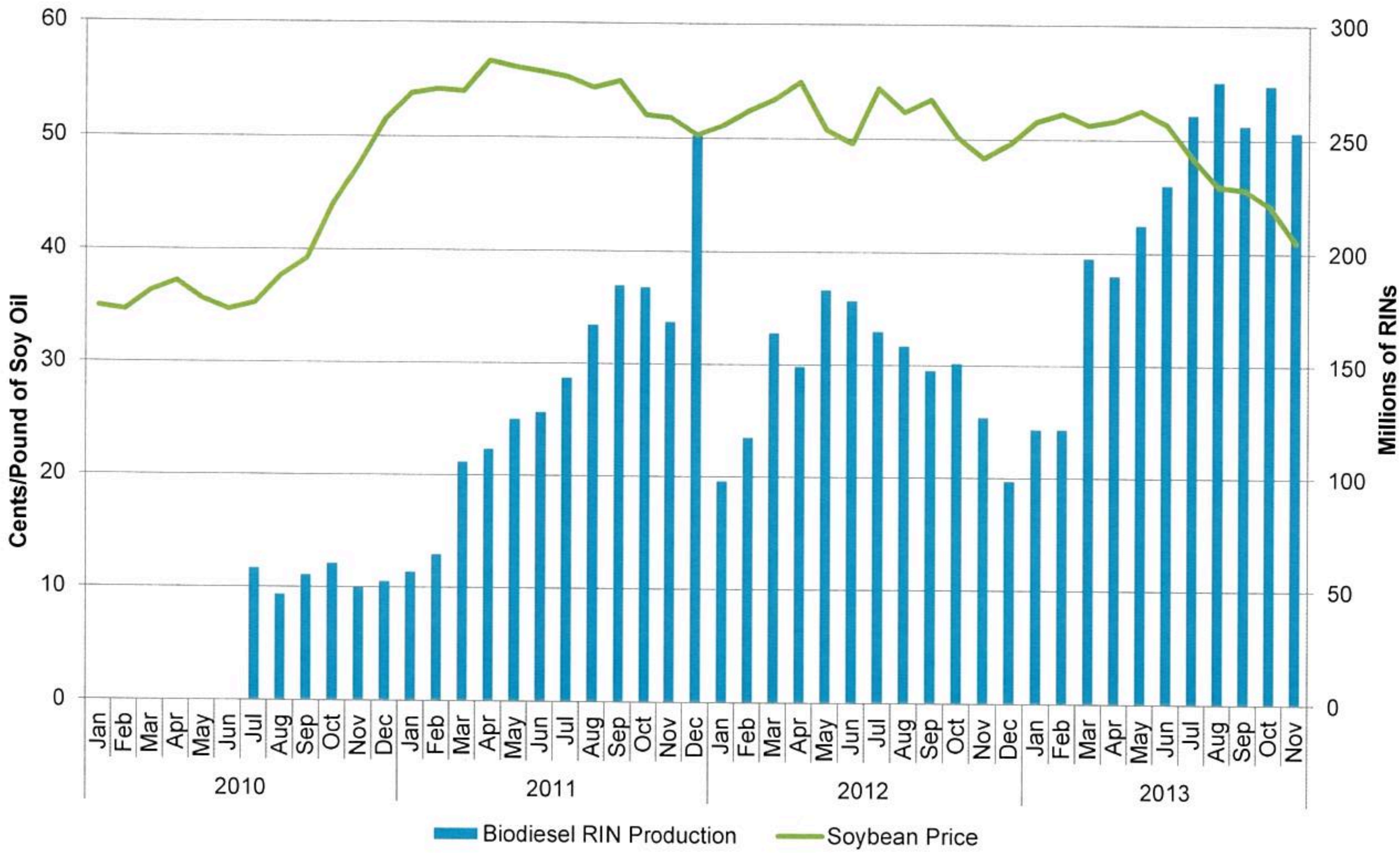
Further increased biodiesel production is not constrained by available feedstocks



Source: LMC International, "Current and Future Supply of RFS2 Qualifying and Non-qualifying Oils and Fats for Biofuels," July 2013.

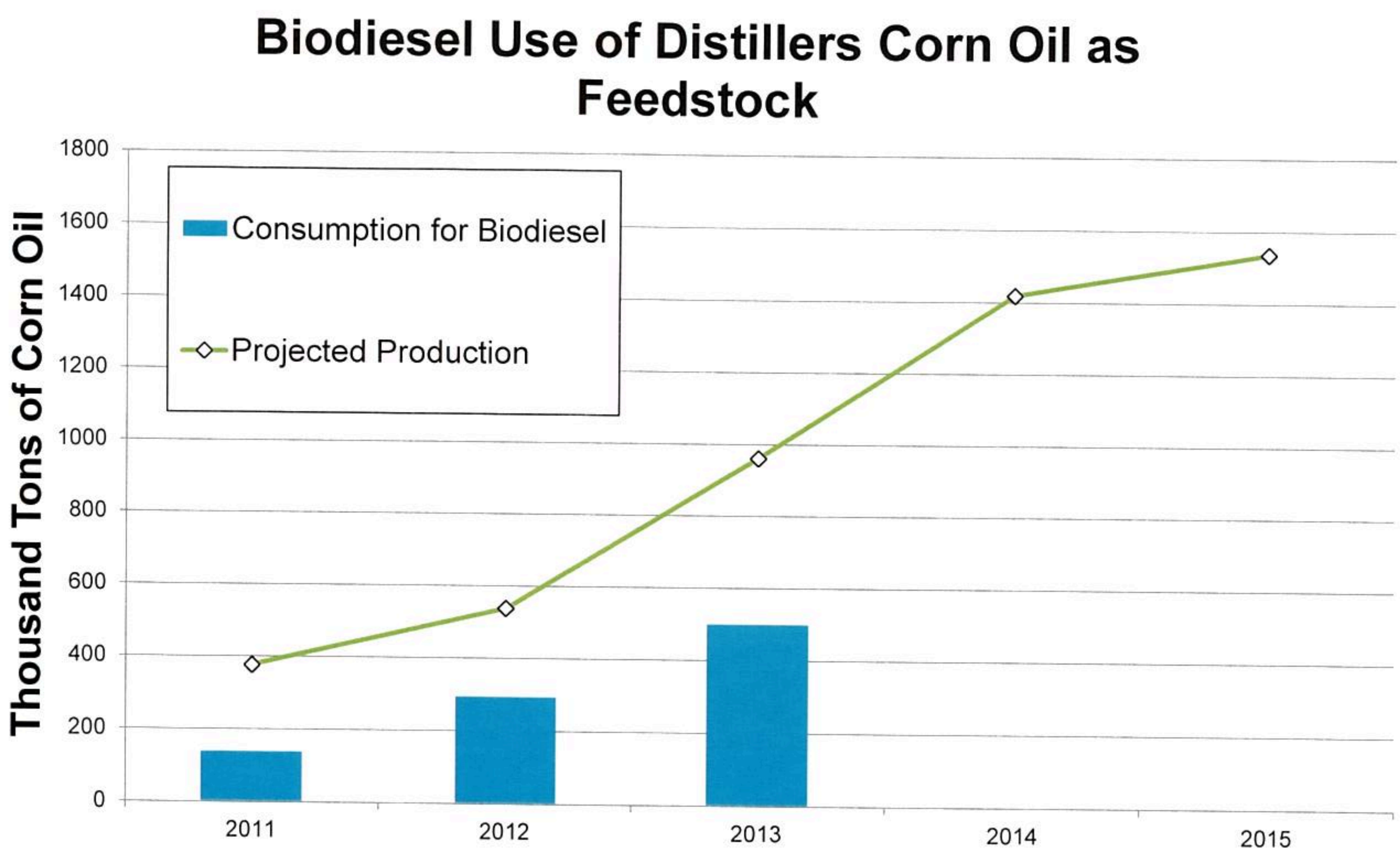
2055

Recent rapid growth in biodiesel has not increased soybean oil prices – additional production is unlikely to cause large feedstock cost increases



Source: Soy Oil prices from Jacobsen; RIN volumes from EPA EMTS database.

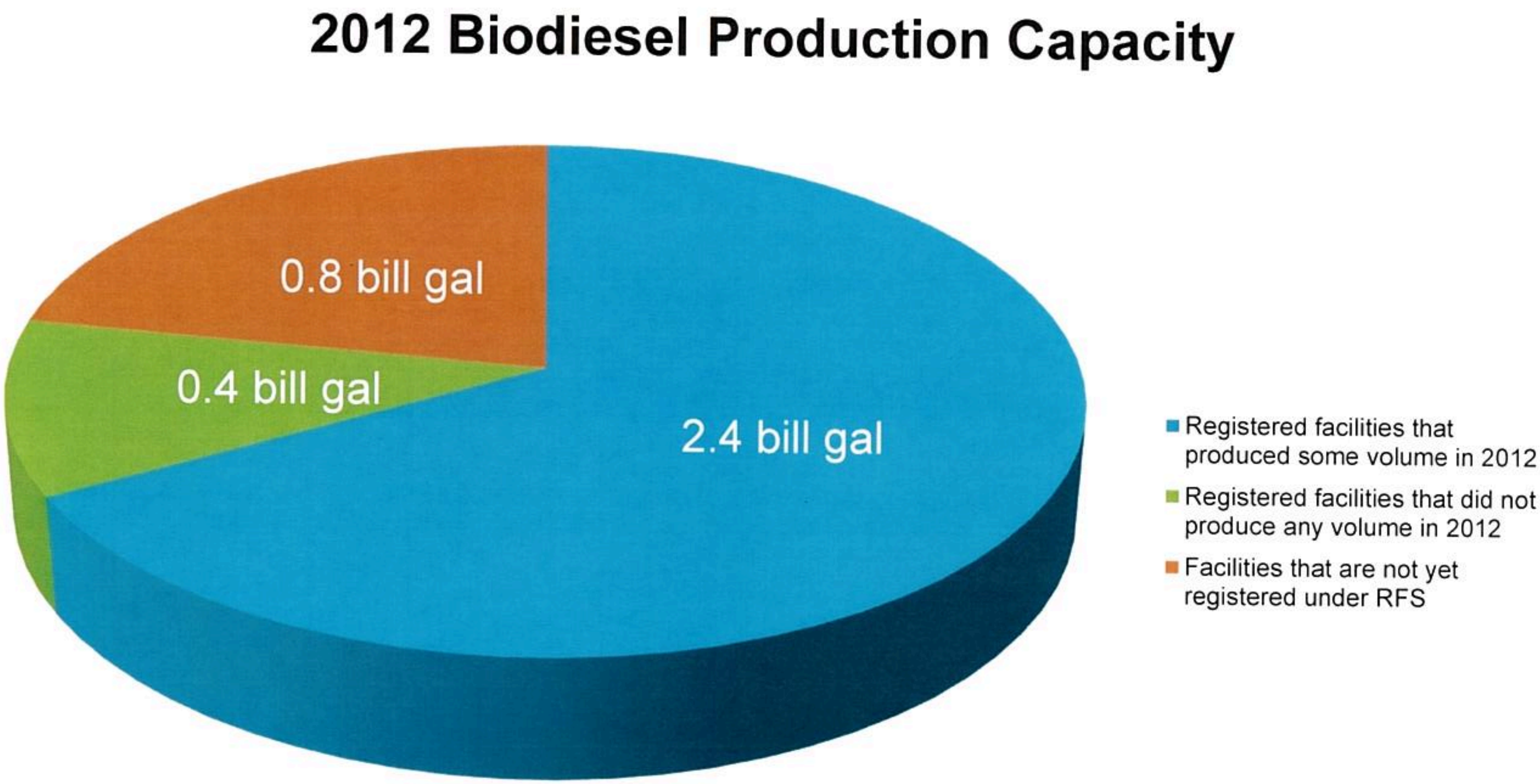
Increasing availability and recent price trends suggest incremental biodiesel production will come from lower carbon feedstocks



Sources: EIA Monthly Biodiesel Production Report, November 2013; LMC International Report, "Current and Future Supply of RFS2 Qualifying and Non-Qualifying Oils and Fats for Biofuels," July 2013.

2055

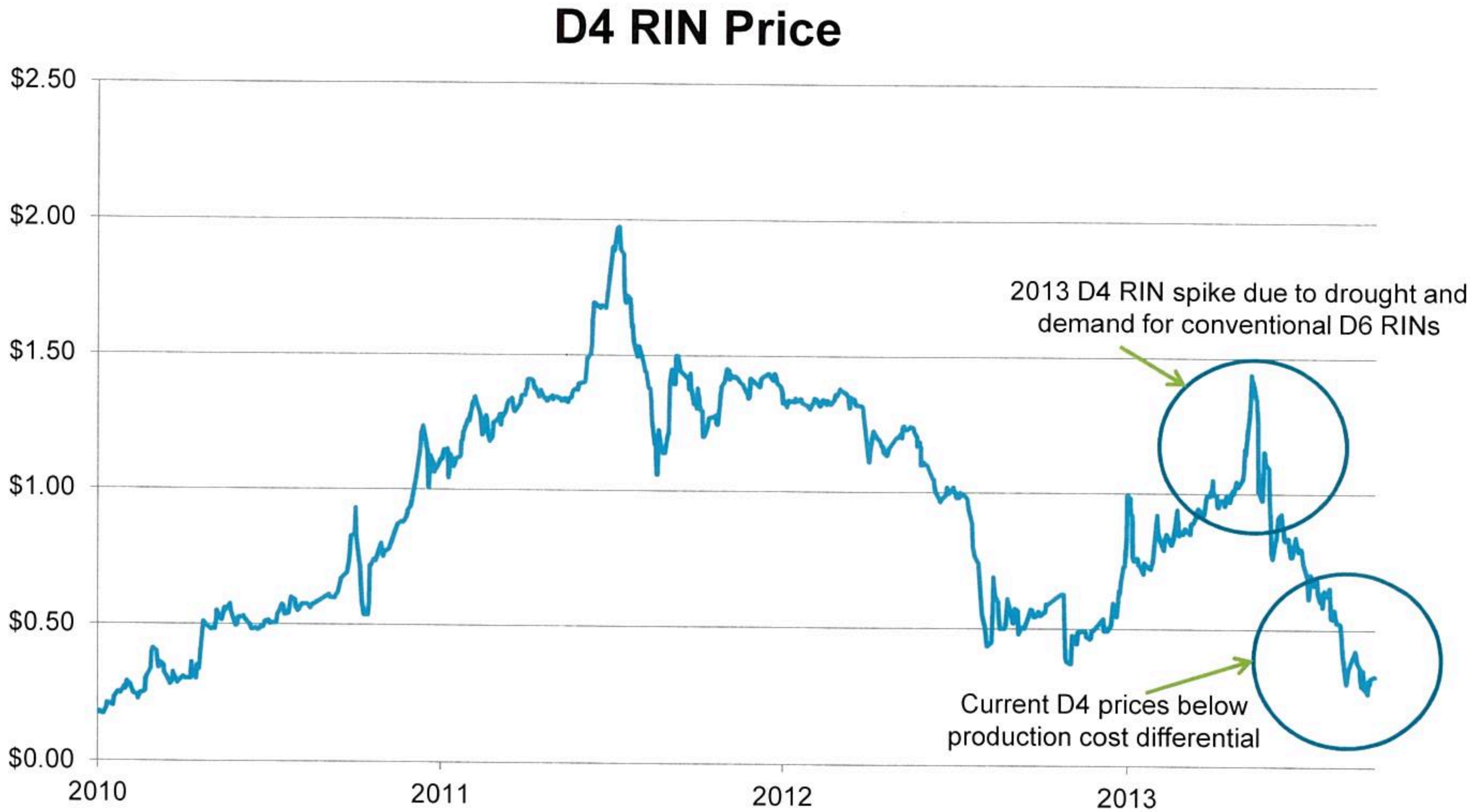
Further increased biodiesel production is not constrained by available biodiesel capacity



Source: Biodiesel plant list 2-6-13 from Docket EPA-HQ-OAR-2013-0479; numbers are from a combination of NBB, EIA, and EPA databases.

2055

D4 RIN prices are currently well below historical levels, reflecting growth in biodiesel supplies and production capacity



Source: Bloomberg; average of available indices.

SSMC

Simulation models suggest biodiesel production can remain at 2013 levels or further expand without significantly increasing costs

	2013		2014 Forecast
Production, billion gallons	**1.74**		**1.70**
Weighted feedstock cost, $/gal	$3.20		$2.70
Avg processing cost, $/gal	$0.50		$0.50
Total Production Cost, $/gal	**$3.70**		**$3.20**
Wholesale Diesel Price, $/gal	$3.01		$2.92
Biodiesel cost differential, $/gal	$0.69		$0.28
Cost of 1 metric ton CO2 reduction	$71		$29

Sources: 2013 production cost analysis with industry processing cost estimate; 2014 production cases from World Agricultural Economic and Environmental Services (WAEES) model.

Current biodiesel cost differential would be largely eliminated by a $43/ton carbon price

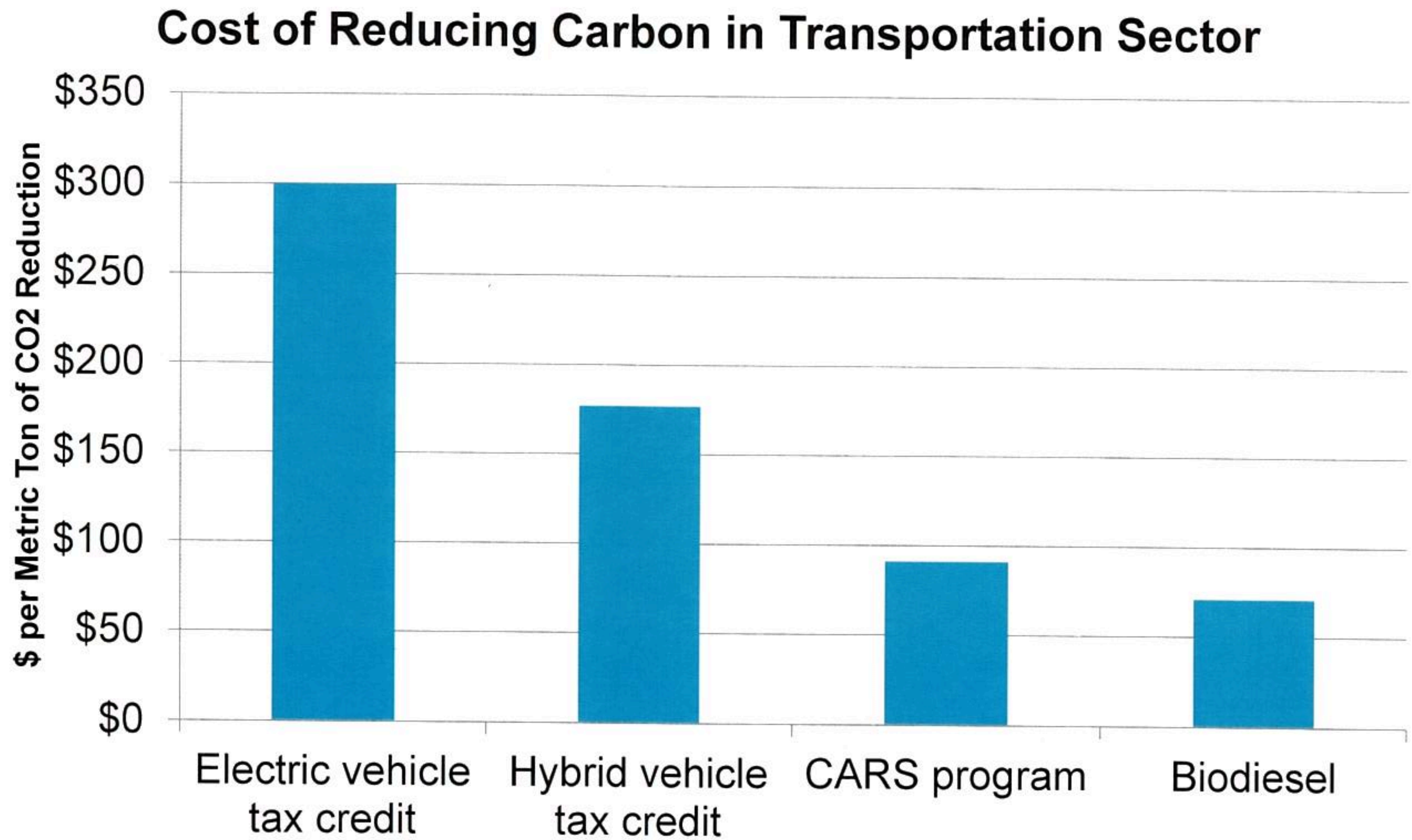
- 2014 projected wholesale price of diesel = $2.92/gallon
- A gallon of diesel fuel produces around 96g CO2e/MJ
- A gallon of diesel fuel has an energy intensity of 36.17 MJ/liter
- With carbon price of $43/ton, diesel price would increase $0.57/gal

$$2.92\ \frac{\$}{gallon} + 96\ \frac{g\ CO_2}{MJ} * 36.17\ \frac{MJ}{liter} * 3.785\frac{liters}{gallon} * .000043\ \frac{\$}{g\ CO_2} = 3.49\ \frac{\$}{gallon}$$

D4 RIN prices of $0.57/gallon are equivalent to a $43/ton carbon tax on petroleum diesel

2655

Biodiesel cost of carbon reduction compares favorably to other policies



Source for data regarding electric vehicle tax credit, hybrid vehicle tax credit, and CARS program: Ted Gayer, "Cash for Clunkers: An Evaluation of the Car Allowance Rebate System," *Economic Studies at Brookings*, October 2013.

2655

	D4 Price
3/9/2010	0.1725
3/11/2010	0.18
3/12/2010	0.175
3/15/2010	0.17
3/17/2010	0.185
3/18/2010	0.19
3/19/2010	0.21
3/23/2010	0.205
3/25/2010	0.2
3/26/2010	0.23
3/30/2010	0.25
4/1/2010	0.25
4/2/2010	0.245
4/6/2010	0.27
4/7/2010	0.26
4/8/2010	0.27
4/9/2010	0.29
4/13/2010	0.275
4/15/2010	0.255
4/16/2010	0.245
4/20/2010	0.24
4/21/2010	0.225
4/22/2010	0.235
4/23/2010	0.2463
4/27/2010	0.25
4/28/2010	0.255
4/29/2010	0.3
4/30/2010	0.31
5/4/2010	0.335
5/5/2010	0.395
5/6/2010	0.41
5/7/2010	0.41
5/11/2010	0.4
5/12/2010	0.36
5/13/2010	0.34
5/14/2010	0.36
5/18/2010	0.35
5/19/2010	0.32
5/21/2010	0.31
5/25/2010	0.28
5/26/2010	0.285
5/27/2010	0.29
5/28/2010	0.325
6/2/2010	0.285
6/4/2010	0.295
6/8/2010	0.3075
6/9/2010	0.305
6/10/2010	0.3
6/11/2010	0.3
6/15/2010	0.3
6/16/2010	0.3
6/17/2010	0.36

6/18/2010	0.325
6/22/2010	0.3
6/23/2010	0.35
6/25/2010	0.335
6/29/2010	0.485
6/30/2010	0.51
7/1/2010	0.505
7/2/2010	0.5
7/7/2010	0.4825
7/8/2010	0.48
7/9/2010	0.485
7/12/2010	0.4825
7/13/2010	0.51
7/14/2010	0.55
7/19/2010	0.515
7/21/2010	0.54
7/22/2010	0.56
7/23/2010	0.55
7/27/2010	0.57
7/28/2010	0.575
7/29/2010	0.55
7/30/2010	0.535
8/3/2010	0.495
8/4/2010	0.495
8/5/2010	0.515
8/6/2010	0.525
8/9/2010	0.525
8/11/2010	0.53
8/12/2010	0.5225
8/17/2010	0.5
8/18/2010	0.5
8/20/2010	0.48
8/23/2010	0.485
8/25/2010	0.485
8/26/2010	0.48
8/27/2010	0.48
8/31/2010	0.495
9/1/2010	0.4888
9/2/2010	0.5
9/3/2010	0.51
9/7/2010	0.515
9/8/2010	0.5025
9/10/2010	0.505
9/15/2010	0.505
9/16/2010	0.5375
9/17/2010	0.54
9/21/2010	0.57315
9/22/2010	0.57
9/24/2010	0.535
9/28/2010	0.54
9/30/2010	0.59
10/1/2010	0.6
10/5/2010	0.59

10/6/2010	0.56
10/7/2010	0.56
10/8/2010	0.55
10/12/2010	0.575
10/13/2010	0.575
10/18/2010	0.575
10/21/2010	0.56
10/22/2010	0.57
11/10/2010	0.61
11/11/2010	0.6
11/16/2010	0.5975
11/17/2010	0.605
11/18/2010	0.6112
11/19/2010	0.6137
11/23/2010	0.67
11/29/2010	0.69
12/1/2010	0.73
12/2/2010	0.775
12/3/2010	0.825
12/7/2010	0.83
12/8/2010	0.93
12/9/2010	0.825
12/13/2010	0.71
12/15/2010	0.5825
12/16/2010	0.56
12/17/2010	0.535
12/21/2010	0.535
12/22/2010	0.575
12/23/2010	0.7175
12/24/2010	0.7175
12/27/2010	0.74
12/29/2010	0.735
12/31/2010	0.755
1/4/2011	0.79995
1/5/2011	0.77
1/6/2011	0.75
1/7/2011	0.7675
1/12/2011	0.7775
1/21/2011	0.87
1/25/2011	0.88
1/26/2011	0.8775
1/28/2011	0.88
1/31/2011	0.9
2/1/2011	0.9225
2/4/2011	0.935
2/10/2011	1.05
2/14/2011	1.15
2/15/2011	1.21
2/16/2011	1.21
2/17/2011	1.235
2/22/2011	1.14
2/23/2011	1.005
2/25/2011	1.125

2/28/2011	1.1
3/1/2011	1.0625
3/2/2011	1.07
3/3/2011	1.0775
3/4/2011	1.08
3/7/2011	1.1075
3/8/2011	1.1125
3/9/2011	1.1125
3/10/2011	1.13
3/11/2011	1.1475
3/14/2011	1.145
3/15/2011	1.15
3/16/2011	1.0425
3/17/2011	1.0625
3/18/2011	1.13
3/21/2011	1.11
3/22/2011	1.085
3/23/2011	1.095
3/24/2011	1.115
3/25/2011	1.115
3/28/2011	1.12
3/29/2011	1.125
3/30/2011	1.18
3/31/2011	1.1825
4/1/2011	1.21
4/5/2011	1.255
4/6/2011	1.26
4/7/2011	1.255
4/8/2011	1.2775
4/11/2011	1.32625
4/12/2011	1.325
4/13/2011	1.345
4/14/2011	1.33
4/15/2011	1.32
4/18/2011	1.2925
4/19/2011	1.275
4/21/2011	1.2025
4/25/2011	1.275
4/26/2011	1.2625
4/27/2011	1.21
4/29/2011	1.18
5/2/2011	1.195
5/3/2011	1.25
5/4/2011	1.25
5/5/2011	1.255
5/6/2011	1.255
5/9/2011	1.27
5/10/2011	1.28
5/11/2011	1.24
5/12/2011	1.28
5/13/2011	1.27
5/16/2011	1.29
5/18/2011	1.32

5/19/2011	1.33
5/20/2011	1.33
5/23/2011	1.34
5/24/2011	1.32
5/25/2011	1.295
5/26/2011	1.29
6/1/2011	1.32
6/2/2011	1.35
6/3/2011	1.35
6/6/2011	1.35
6/7/2011	1.37
6/8/2011	1.375
6/9/2011	1.41
6/13/2011	1.41
6/14/2011	1.405
6/15/2011	1.4
6/16/2011	1.375
6/17/2011	1.38
6/21/2011	1.345
6/22/2011	1.35
6/23/2011	1.37
6/24/2011	1.36
6/27/2011	1.34
6/28/2011	1.34
6/29/2011	1.33
6/30/2011	1.33
7/1/2011	1.34
7/5/2011	1.35
7/6/2011	1.335
7/7/2011	1.345
7/11/2011	1.345
7/12/2011	1.34
7/13/2011	1.34
7/14/2011	1.34
7/15/2011	1.33
7/18/2011	1.34
7/19/2011	1.33
7/20/2011	1.335
7/21/2011	1.325
7/22/2011	1.34
7/25/2011	1.3425
7/26/2011	1.36
7/27/2011	1.37
7/28/2011	1.37
7/29/2011	1.375
8/1/2011	1.37
8/2/2011	1.395
8/8/2011	1.4
8/9/2011	1.405
8/10/2011	1.45
8/11/2011	1.49
8/12/2011	1.49
8/15/2011	1.505

8/16/2011	1.54
8/17/2011	1.635
8/18/2011	1.695
8/19/2011	1.695
8/22/2011	1.685
8/23/2011	1.68
8/25/2011	1.675
8/26/2011	1.685
8/29/2011	1.68
8/31/2011	1.675
9/6/2011	1.855
9/7/2011	1.9
9/8/2011	1.885
9/9/2011	1.89
9/12/2011	1.97
9/13/2011	1.97
9/14/2011	1.975
9/15/2011	1.92
9/16/2011	1.89
9/19/2011	1.875
9/20/2011	1.75
9/21/2011	1.7
9/22/2011	1.695
9/23/2011	1.72
9/26/2011	1.71
9/27/2011	1.67
9/28/2011	1.605
9/29/2011	1.61
9/30/2011	1.55
10/4/2011	1.495
10/5/2011	1.535
10/6/2011	1.535
10/11/2011	1.475
10/13/2011	1.44
10/14/2011	1.44
10/17/2011	1.38
10/18/2011	1.38
10/19/2011	1.375
10/20/2011	1.325
10/21/2011	1.255
10/24/2011	1.17
10/25/2011	1.17
10/26/2011	1.06
10/27/2011	1.06
10/28/2011	1.225
10/31/2011	1.16
11/1/2011	1.16
11/2/2011	1.14
11/3/2011	1.14
11/4/2011	1.14
11/7/2011	1.21
11/8/2011	1.21
11/9/2011	1.4

11/11/2011	1.45
11/14/2011	1.395
11/15/2011	1.395
11/16/2011	1.5
11/17/2011	1.5
11/18/2011	1.5
11/21/2011	1.44
11/22/2011	1.44
11/23/2011	1.435
11/28/2011	1.42
11/29/2011	1.42
11/30/2011	1.375
12/1/2011	1.435
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12/5/2011	1.32
12/6/2011	1.32
12/7/2011	1.33
12/8/2011	1.305
12/9/2011	1.38
12/12/2011	1.3
12/13/2011	1.3
12/14/2011	1.295
12/15/2011	1.2
12/16/2011	1.2
12/19/2011	1.23
12/20/2011	1.255
12/21/2011	1.27
12/27/2011	1.275
12/28/2011	1.28
12/29/2011	1.25
12/30/2011	1.245
1/3/2012	1.3875
1/4/2012	1.39
1/5/2012	1.4
1/6/2012	1.4
1/9/2012	1.4525
1/10/2012	1.445
1/11/2012	1.4475
1/12/2012	1.4125
1/13/2012	1.43
1/17/2012	1.42
1/18/2012	1.425
1/20/2012	1.42
1/23/2012	1.4025
1/24/2012	1.4
1/25/2012	1.3975
1/26/2012	1.395
1/30/2012	1.365
1/31/2012	1.365
2/1/2012	1.3425
2/2/2012	1.355
2/3/2012	1.4175
2/13/2012	1.385

2/14/2012	1.415
2/15/2012	1.42
2/22/2012	1.435
2/23/2012	1.43
2/24/2012	1.425
2/27/2012	1.41
2/28/2012	1.435
2/29/2012	1.43
3/1/2012	1.415
3/2/2012	1.4
3/5/2012	1.39
3/6/2012	1.38375
3/7/2012	1.3675
3/8/2012	1.325
3/9/2012	1.3375
3/12/2012	1.3125
3/13/2012	1.33
3/14/2012	1.3375
3/15/2012	1.3325
3/16/2012	1.3325
3/19/2012	1.335
3/20/2012	1.33
3/21/2012	1.345
3/22/2012	1.3325
3/27/2012	1.3425
3/28/2012	1.3275
4/3/2012	1.3175
4/5/2012	1.305
4/9/2012	1.3325
4/10/2012	1.345
4/11/2012	1.3325
4/12/2012	1.3425
4/13/2012	1.3325
4/16/2012	1.315
4/17/2012	1.32
4/18/2012	1.335
4/19/2012	1.34
4/20/2012	1.335
4/23/2012	1.3225
4/24/2012	1.3375
4/25/2012	1.3275
4/26/2012	1.325
4/27/2012	1.3225
5/1/2012	1.34
5/2/2012	1.36
5/3/2012	1.36
5/4/2012	1.355
5/7/2012	1.38
5/8/2012	1.3725
5/9/2012	1.3725
5/14/2012	1.3625
5/16/2012	1.35
5/17/2012	1.31

5/18/2012	1.35
5/21/2012	1.34
5/22/2012	1.3425
5/24/2012	1.32
5/30/2012	1.3175
5/31/2012	1.3125
6/7/2012	1.11
6/8/2012	1.155
6/11/2012	1.225
6/12/2012	1.22
6/13/2012	1.205
6/14/2012	1.21
6/15/2012	1.2
6/18/2012	1.19
6/19/2012	1.18
6/20/2012	1.17
6/21/2012	1.17
6/22/2012	1.145
6/25/2012	1.135
6/26/2012	1.14
6/27/2012	1.16
7/5/2012	1.2
7/6/2012	1.2
7/9/2012	1.21
7/10/2012	1.215
7/11/2012	1.2
7/12/2012	1.24
7/13/2012	1.245
7/16/2012	1.23
7/19/2012	1.2375
7/20/2012	1.2425
7/23/2012	1.23875
7/24/2012	1.225
7/27/2012	1.2025
7/30/2012	1.185
7/31/2012	1.165
7/27/2012	1.17
7/30/2012	1.17
7/31/2012	1.1
8/1/2012	1.1
8/2/2012	1.1
8/3/2012	1.11
8/6/2012	1.1
8/7/2012	1.1
8/13/2012	1.05
8/14/2012	1.05
8/15/2012	1.02
8/16/2012	1
8/20/2012	0.975
8/21/2012	0.965
8/22/2012	0.975
8/27/2012	0.99
8/28/2012	1.02

8/29/2012	1.005
8/30/2012	0.995
9/4/2012	1.02
9/5/2012	1
9/6/2012	1
9/7/2012	0.98
9/10/2012	0.98
9/11/2012	1
9/12/2012	0.995
9/14/2012	0.99
9/17/2012	0.985
9/19/2012	0.975
9/20/2012	0.94
9/24/2012	0.885
9/25/2012	0.8
9/26/2012	0.78
9/27/2012	0.765
10/1/2012	0.74
10/2/2012	0.69
10/5/2012	0.55
10/8/2012	0.505
10/10/2012	0.435
10/15/2012	0.45
10/16/2012	0.55
10/17/2012	0.69
10/19/2012	0.62
10/22/2012	0.6
10/24/2012	0.5
10/25/2012	0.5
10/29/2012	0.5
10/30/2012	0.51
11/1/2012	0.61
11/5/2012	0.55
11/6/2012	0.54
11/7/2012	0.52
11/8/2012	0.56167
11/9/2012	0.57333
11/12/2012	0.56667
11/13/2012	0.48
11/16/2012	0.505
11/19/2012	0.5
11/26/2012	0.57167
11/27/2012	0.57
11/28/2012	0.55833
11/29/2012	0.54333
11/30/2012	0.54333
12/3/2012	0.55
12/4/2012	0.56333
12/5/2012	0.55833
12/6/2012	0.54667
12/10/2012	0.56167
12/11/2012	0.56
12/12/2012	0.59

12/13/2012	0.58667
12/28/2012	0.62667
12/31/2012	0.62667
1/2/2013	0.395
1/3/2013	0.38
1/7/2013	0.3725
1/8/2013	0.3725
1/9/2013	0.475
1/10/2013	0.475
1/14/2013	0.445
1/15/2013	0.49
1/16/2013	0.49
1/17/2013	0.49
1/18/2013	0.49
1/21/2013	0.49
1/22/2013	0.49
1/23/2013	0.49
1/24/2013	0.47
1/25/2013	0.47
1/28/2013	0.4625
1/29/2013	0.4675
1/30/2013	0.495
1/31/2013	0.495
2/1/2013	0.495
2/11/2013	0.5375
2/12/2013	0.4925
2/13/2013	0.4925
2/14/2013	0.4925
2/15/2013	0.4925
2/19/2013	0.515
2/21/2013	0.595
2/22/2013	0.5775
2/25/2013	0.545
2/27/2013	0.64
2/28/2013	0.63
3/1/2013	0.67
3/4/2013	0.73
3/5/2013	0.73
3/6/2013	0.765
3/7/2013	0.825
3/8/2013	0.995
3/11/2013	0.9825
3/12/2013	0.925
3/13/2013	0.92
3/14/2013	0.765
3/15/2013	0.75
3/18/2013	0.76
3/19/2013	0.76
3/20/2013	0.735
3/21/2013	0.735
3/25/2013	0.7025
3/26/2013	0.745
4/1/2013	0.7225

4/2/2013	0.72
4/3/2013	0.735
4/4/2013	0.745
4/8/2013	0.89
4/9/2013	0.92
4/10/2013	0.855
4/12/2013	0.8275
4/16/2013	0.79
4/17/2013	0.83
4/19/2013	0.85
4/22/2013	0.83
4/23/2013	0.82
4/24/2013	0.81
4/25/2013	0.82
4/26/2013	0.83
4/30/2013	0.94
5/1/2013	0.9
5/2/2013	0.845
5/3/2013	0.86
5/6/2013	0.85
5/7/2013	0.855
5/8/2013	0.87
5/9/2013	0.87
5/13/2013	0.855
5/14/2013	0.85
5/15/2013	0.89
5/16/2013	0.89
5/17/2013	0.89
5/20/2013	0.915
5/21/2013	0.935
5/22/2013	0.945
5/23/2013	0.94
5/24/2013	0.915
5/27/2013	0.92
5/28/2013	0.925
5/29/2013	0.955
5/30/2013	0.98
5/31/2013	0.995
6/3/2013	0.99
6/4/2013	1.01
6/5/2013	1.01
6/6/2013	1.05
6/7/2013	0.995
6/10/2013	0.995
6/11/2013	0.955
6/12/2013	0.95
6/13/2013	0.965
6/14/2013	0.975
6/17/2013	0.975
6/18/2013	0.965
6/19/2013	0.955
6/20/2013	0.985
6/21/2013	0.995

6/24/2013	0.97
6/25/2013	0.985
6/26/2013	1.005
6/27/2013	1.0125
6/28/2013	1
7/1/2013	1.045
7/2/2013	1.03
7/3/2013	1.025
7/8/2013	1.055
7/9/2013	1.0825
7/10/2013	1.165
7/11/2013	1.145
7/12/2013	1.195
7/15/2013	1.2875
7/16/2013	1.35
7/17/2013	1.44
7/18/2013	1.415
7/19/2013	1.415
7/22/2013	1.355
7/23/2013	1.3475
7/24/2013	1.27
7/25/2013	1.005
7/26/2013	1.005
7/29/2013	0.975
7/30/2013	1.075
7/31/2013	1.155
8/1/2013	1.115
8/5/2013	1.095
8/6/2013	0.975
8/7/2013	0.88333
8/8/2013	0.78
8/9/2013	0.76
8/12/2013	0.82
8/13/2013	0.83
8/15/2013	0.91
8/16/2013	0.91667
8/19/2013	0.92667
8/20/2013	0.87667
8/21/2013	0.86667
8/22/2013	0.83
8/23/2013	0.82667
8/26/2013	0.83667
8/27/2013	0.81667
8/28/2013	0.78667
8/29/2013	0.76667
8/30/2013	0.76667
9/3/2013	0.84
9/4/2013	0.81667
9/5/2013	0.80667
9/6/2013	0.78667
9/9/2013	0.79667
9/10/2013	0.78667
9/11/2013	0.74667

9/12/2013	0.73667
9/13/2013	0.72333
9/16/2013	0.69333
9/17/2013	0.61333
9/18/2013	0.64333
9/19/2013	0.70333
9/20/2013	0.69333
9/23/2013	0.66333
9/24/2013	0.66333
9/25/2013	0.67333
9/26/2013	0.68333
9/27/2013	0.63333
9/30/2013	0.60333
10/1/2013	0.63333
10/2/2013	0.58333
10/3/2013	0.62333
10/4/2013	0.64333
10/7/2013	0.63333
10/8/2013	0.62333
10/9/2013	0.65333
10/10/2013	0.65333
10/11/2013	0.54333
10/14/2013	0.54
10/15/2013	0.57333
10/16/2013	0.55333
10/17/2013	0.52667
10/18/2013	0.52667
10/21/2013	0.52333
10/22/2013	0.51333
10/23/2013	0.46333
10/24/2013	0.41333
10/28/2013	0.30333
10/30/2013	0.35667
11/6/2013	0.42333
11/7/2013	0.41333
11/8/2013	0.38333
11/11/2013	0.36333
11/12/2013	0.31
11/13/2013	0.29333
11/14/2013	0.35333
11/15/2013	0.28667
11/18/2013	0.27667
11/19/2013	0.26667
11/20/2013	0.315
11/21/2013	0.30333
11/22/2013	0.32333
11/26/2013	0.33
11/27/2013	0.33

To resize chart data range, drag lower right corner of range.

	Sales
Registered fa	2.4
Registered fa	0.4
Facilities tha	0.8

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Year	ConsumpticProjected Production	
2011	138	377
2012	293	538
2013	500	961
2014		1419
2015		1536

Distillers C	metric tonnes
304	137.93103
646	293.10345
1102	500

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	Best Available		
regular diese	27.9		
canola	12.9		
soy	6.2		
used cooking	3.7		
other recycle	3.7		
animal fat	3.7		
distillers corr	1.2		

		USDA/Idaho	0.764	soy	89.7	96	27.91197
soy	0.5	USDA/Idaho	0	soy	96	96	27.91197
corn oil	0.1	CARB 2011	0.95833	corn oil	96	4	1.16300
used cooking oil	0.1	USEPA 2010	0.86919	waste grea	96	12.558	3.65123
other recycled grease	0.03	USEPA 2010	0.86919	waste grea	96	12.558	3.65123
animal fat	0.13	USEPA 2010	0.86919	waste grea	96	12.558	3.65123
renewable diesel	0.1	CARB 2011	0.79531	tallow RD	96	19.65	5.71323
canola	0.04	USEPA 2010	0.53748	canola	96	44.4015	12.90972

	Series 1
Electric vehicle tax credit	300
Hybrid vehicle tax credit	177
CARS program	91
Biodiesel	71

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2661

Year	Gallons / Metric ton of Carbon	GHG reduction in lbs CO2e/gallon of biodiesel	Conversion to Tons	Gallons / Ton
2011	109	20.2	0.00916	109.13973
2012	107	20.7	0.00939	106.50351
2013	104	21.3	0.00966	103.50341

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Year	Biodiesel ProductiorDistillers Co		Biodiesel Production2	Soybean a	Corn, Tallow, Yellow Grease a	
2011	1,122,699,193.00	34%	,122,699,193	5000	2549	0.33769
2012	1,146,899,177.00	40%	1146899177	4832	3218	0.39978
2013	1,740,915,464.00	47%	1740915464	4131	3722	0.47398

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1740915464

nd other Oils

year	2011	2012	2013
Production Cost of Biodiesel	$ 4.57	$ 4.32	$ 3.89
Wholesale Price of Diesel	$ 3.05	$ 3.11	$ 3.01
Difference	$ 1.52	$ 1.21	$ 0.88

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	Based on Iowa Sta	Based on NBB processing cost estimates
2011	$ 166	$ 158
2012	$ 128	$ 121
2013	$ 91	$ 71

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	Soybean Oi	Distiller's Cc	Column1
2011	4.05598	2.98403	
2012	3.87813	2.92350	
2013	3.65178	2.65779	

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2666

year	2011	2012	2013
Production Cost of Biodiesel	$ 4.57	$ 4.32	$ 3.89
Wholesale Price of Diesel	$ 3.05	$ 3.11	$ 3.01
Based on Iowa State processing cost estimate	$ 1.52	$ 1.21	$ 0.88
Based on NBB processing cost estimates	$ 1.45	$ 1.15	$ 0.69

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